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An analysis of the Edmonton test of equivalence in mathematics.

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THE UNIVERSITY OF ALBERTA

# AN ANALYSIS OF THE EDMONTON TEST OF EQUIVALENCE IN MATHEMATICS

A DISSERTATION SUBMITTED
TO THE COMMITTEE ON GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE DEGREE OF
MASTER OF EDUCATION

FACULTY OF EDUCATION

BY

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The undersigned hereby certify that they have read and do recommend to the Committee on Graduate Studies for acceptance, a thesis entitled "An Analysis of the Edmonton Test of Equivalence in Mathematics," submitted by Aurora L. Biamonte, B.A., B.Ed., in partial fulfilment of the requirements for the degree of Master of Education.

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## SYNOPSIS

Though many standardized mathematics tests are available for use in the classroom, few are keyed to the newer conceptions of mathematics. The main purpose of this study was to evaluate an achievement test in mathematics purporting to measure comprehension of fundamental relationships in mathematics at the Grade IX level. Three hundred Grade IX pupils were administered the two forms of the test and an analysis made of the results.

The test was first analyzed to determine the degree to which it met the criteria of reliability and validity required of a standardized test. Two measures of reliability were found by the methods of parallel forms and rational equivalence, while three measures of validity were determined by correlating the test scores against external criteria by the product-moment technique. The same technique was used to determine the reliability of each subtest and the intercorrelations of the four subtests. An item analysis of the test was also made using the Davis Item Analysis Chart, and finally the forms were studied for comparability.

Though reliability and validity measures were lowered by the restricted sample used in this study, the test appeared sufficiently reliable and valid for use in classroom guidance in mathematics. The need for revision and for rearrangement of the order of the items in the test were strongly indicated by item analysis. Form B of the test seemed a less valid instrument for measuring achievement in mathematics than Form A.

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# CHAPTER I

## AN APPROACH TO THE TESTING OF MATHEMATICS

### HISTORICAL BACKGROUND

Not until the eighteenth century did arithmetic appear as a subject on the curriculum of American schools. Conceived as an essential tool in business, the utilitarian aspects of arithmetic were stressed by teachers until 1800. With the publication in 1821 of Colburn's 'First Lessons', [1] the purpose of instruction in arithmetic changed. Reflecting the doctrine of mental faculties prevalent in the philosophy of the era, mathematics, through the inductive approach, became a recognized means of disciplining and developing the mind. Colburn and those who followed him in the nineteenth century made little change in the content of arithmetic; their chief contributions were in the field of instructional procedures.

By the beginning of the twentieth century educators turned from considerations of method to discussions of content of arithmetic courses in terms of purpose to be achieved. In 1934, the Ninth Yearbook of the National Council of the Teachers of Mathematics stated, "Broadly considered, the aims of most teachers of mathematics may be summarized under three main headings: utilitarian, disciplinarian and cultural. Functional mathematics affords (us) an ideal medium through which these aims may be realized." [2] The Yearbook emphasized that "the recognition, interpretation and utilization of relationships are the heart and soul of functional thinking." [3]

Clarification of the objectives of instruction in mathematics has been accompanied by a parallel movement in the direction of consideration of the degree to which these goals have been achieved. The written examination did not become an established practice in the United States until after 1850. The refinement of instruments and techniques of evaluation had its beginnings in the work of Horace Mann. The development of these instruments was given impetus by the scientific work in measurement of Wundt, De Moivre, Bessel, Quetelet, Darwin, Galton and Pearson. In 1908 Stone published the first standardized achievement test; it was a test of achievement in elementary arithmetic.

## MEASUREMENT

The most common function of achievement tests is the appraising of learning in a single subject area. An achievement test is standardized when, "the test procedure and content have been so fixed that subjects at different places and times may be compared."[4] The tests usually have norms which permit the interpretation of results.

Standardized tests are of three types, survey, prognostic and diagnostic. The survey and prognostic tests are both general tests whose purpose is to determine all-over competency in mathematics. While both stress the test score as a measure of present achievement, the prognostic test has the additional function of predicting future success. The diagnostic test, unlike the other measures, is designed to identify particular strengths and weaknesses of the individual child, and, within reasonable limits, to reveal the underlying causes. "Diagnostic tests focus on the process by which the subject responds, rather than the product."[5] Since the tests emphasize "intra-individual comparison"

"rather than comparison with others",[6] they are rarely standardized.

## WEAKNESSES IN THE TESTING PROGRAM

Testing programs today have become a routine part of most educational systems. Yet the measuring instruments have tended to evaluate mechanical proficiency in subject matter through more or less stereotyped answers to factual items, rather than measurement of understanding of concepts, techniques and principles through thoughtful answers to functional questions. Cronback feels that few standardized tests have employed tests of ability to apply principles, to reason, or to interpret materials. He cites the work of the Progressive Educational Association in the fields of science and social studies as examples of this type of testing.[7] Reiterating Cronback, and many others in the field, Monroe feels:

> The greatest need in the achievement-testing field is for the development of types of test exercises more consonant with evolving educational objectives. The statistical techniques for determining validity and reliability, for item analysis, and for expressing scores in meaningful ways have outrun the quality of the tests. The construction of items, which measure and encourage socially valid, highly functional, generalized and permanent learning and which stimulate achievement to capacity, is greatly needed in every field of achievement. To build such items requires rare insight into the meanings of education and the function of each subject area in modified human behaviour in desirable directions. When such tests are available teachers and students alike will work toward clarified goals with greater efficiency.[8]

# CHAPTER II

# THE PROBLEM

## CONTENT OF CURRENT ACHIEVEMENT TESTS IN MATHEMATICS

Current achievement tests measure mathematical proficiency in the area of general mathematics or in the specific fields of arithmetic, algebra, geometry, trigonometry or calculus. Achievement on these tests is usually expressed in the form of a total score, or a total score together with a group of subtest scores for each area tested. Examples may be cited: the Foust-Schorling Test of Functional Thinking in Mathematics gives a single test score of achievement in functional thinking; the Cooperative Mathematics Tests for Grades 7, 8 and 9 yield separate scores for the following areas: Part I, Skills; Part II, Facts, Terms and Concepts; Part III, Application; Part IV, Appreciation; the Iowa Every Pupil Test of Basic Skills has three subscores: Part I, Vocabulary and Functional Knowledge; Part II, Fundamental Operations, Section A: Whole Numbers and Fractions, Section B: Percentage, Decimals and Denominate Numbers; Part III, Problems.

## CRITICISM OF CURRENT TESTS IN MATHEMATICS

In recent years, the content of current achievement tests has been severely criticized. The inherent weakness in their content is indicated by the reviews in the Third Mental Measurements Yearbook, edited by Buros. Some of the criticisms of experts in this field may show the present trend of opinion concerning tests of mathematical knowledge. "The test is strong in measurement of skills and processes but weak in measurement of concepts, functional thinking and generalizations."[9]

"...the items are of a very routine variety."[10] "With increasing diversity of first year mathematics courses, the primary objective of this test becomes increasingly futile. Whether mathematical achievement is adequately measured in terms of recognition and one-step computation is also open to debate."[11] "This judgment may, however, reflect the reviewer's belief that evaluation in arithmetic has for too long been narrowly conceived and that any competent attempt to broaden the base of evaluation is welcome."[12] Perhaps a comment by Brueckner epitomizes what is generally felt to be the problem.

> Although elaborate statistical devices were employed in the preparation of the test, that alone does not guarantee usefulness. That depends upon the way in which the tests fit the demands of arithmetic in the present day schools. What is basic in the teaching of arithmetic in the schools, today, therefore, should be measured in such a way that teachers can make a direct application of test findings to their teaching.[13]

It is evident that few tests fulfill the objectives of mathematics. There is a great need for better instruments for testing mathematical achievement.

## THE EDMONTON TEST OF EQUIVALENCE IN MATHEMATICS

The Edmonton Test of Equivalence in Mathematics, constructed by the writer while teaching on the Edmonton Separate School Staff, was planned with the aim of avoiding some of the faults of existing tests. By choice of area and type of item it was hoped to avoid the evaluation of learned processes of textbook mathematics and to reduce the emphasis on manipulation and the mechanical aspects of the subject. The test is at the Grade IX level and has two forms. Each form has four component scores, Computation, Denominate Number, Algebra and Geometry.

## THE PROBLEM

Many claims may be made for a test of achievement, but these claims must be substantiated through statistical analysis. The objective of this study is to ascertain the degree to which Forms A and B of the Edmonton Test of Equivalence in Mathematics for Grade IX meet the technical criteria of good tests. This will be done by:

a. determining the reliability of the test,

b. determining the validity of the test,

c. making an item-analysis of the test,

d. determining the reliability of each subtest,

e. determining the intercorrelations of the subtests,

f. comparing the forms of the test for equivalence.

## CHAPTER III

## THE EDMONTON TEST OF EQUIVALENCE IN MATHEMATICS

Since the major objective of this study is an analysis of the Edmonton Test of Equivalence in Mathematics, a detailed description of the test is provided in this chapter. The Edmonton Test of Equivalence is a test of seventy items designed for the Grade IX level of achievement in mathematics. It has two forms, each having thirty-five multiple-choice items comprising Part I of the test and thirty-five completion type items comprising Part II of the test. Parts I and II have time limits of twenty and twenty-five mimutes respectively. Copies of Forms A and B are found in Appendix A.

As the Grade IX mathematics course is divided into three sections, arithmetic, algebra and geometry, items were devised in each of the three areas. The items could not be distributed evenly as the arithmetic is the culmination of eight years of work in that field, while the algebra is a first-year course and the geometry very elementary in content. Following the emphasis of the Grade IX test, the arithmetic items were subdivided into two separate scores, computation and denominate number. While items cannot be isolated as belonging purely in any one of these fields, they were classified as being predominantly in the field of computation, denominate number, algebra or geometry. The distribution of the items in the four areas is shown in Table I and the classification of the seventy items is indicated by Table II. Since the items in the alternate forms were designed to parallel each other in content as much as possible, Forms A and B have the same distribution and classification of items.

TABLE I : DISTRIBUTION OF ITEMS ON THE FOUR SUBTESTS

| | Part I | Part II | Total |
|---|---|---|---|
| Computation | 23 | 6 | 29 |
| Denominate Number | | 8 | 8 |
| Algebra | 12 | 6 | 18 |
| Geometry | | 15 | 15 |
| Total | 35 | 35 | 70 |

TABLE II : CLASSIFICATION OF ITEMS IN THE EDMONTON TEST OF EQUIVALENCE IN MATHEMATICS

| | Item Number | |
|---|---|---|
| | Part I | Part II |
| Computation | 1, 2, 4, 5, 7, 9,10,11,14,16, 17,18,19,20,22, 23,25,27,28,29, 32,34,35 | 5, 7, 16, 17, 31,33 |
| Denominate Number | | 1,2,3,4,8, 18,19,23 |
| Algebra | 3, 6, 8, 12, 13 15,21,24,26,30 31,33 | 6,14,15,26, 29,30 |
| Geometry | | 9,10,11,12, 13,20,21,22, 24,25,27,28,32, 34,35 |

The items of each of Parts I and II of the tests were arranged in what was thought to be increasing order of difficulty. This posed

a serious problem, for Part I had two subtest scores and Part II had four subscores. Consequently, each of these sets of subtest items had to be arranged according to its own continuum of difficulty.

As an achievement test in mathematics, the purpose of the Edmonton Test of Equivalence was to measure knowledge of the flexibility of mathematical relationships. It was hoped that the test would be consistent with the objectives of the mathematics course and so in content fulfill an essential requirement of a good test.

## CHAPTER IV

### THE PLAN OF APPRAISAL OF THE TEST

The test was administered in June 1952 to the entire population of Grade IX students of the Edmonton Separate Schools. A copy of the two forms of the test and the Directions For Administration are found in Appendix A. Both forms of the test were administered to the pupils on the same day. In an attempt to minimize practice effect, the pupils were arbitrarily divided into two groups. Group I was given Form A in the morning and Form B in the afternoon, while Group II was administered B in the morning and A in the afternoon. To insure uniformity in scoring, all tests were checked, scored and recorded by a group of students under the supervision of the writer. The results obtained provided the data for the analysis of the test.

### RELIABILITY AND VALIDITY

Every worthwhile standardized test must possess reliability and validity. The extent to which repeated measurements give consistent results for an individual is termed a measure of the reliability of the test. To avoid testing computational skill, the Test of Equivalence had to be administered as a speed test. The various procedures for estimating reliability are inappropriate for such tests since the amount accomplished within the time limit is the measure of achievement. Two independently timed estimates of the score that could be obtained within the limited period of time are necessary. Single administrations could give two such estimates by means of a technique such as the split-half but these measures are not strictly applicable to timed tests, therefore,

reliability estimates of the Edmonton Test of Equivalence must be based on the repeated administration of each form or the administration of equivalent forms.[14] Garrett, however, suggests that a simple approximation of the formula of rational equivalence could be used to give a quick estimate of reliability of tests. This measure, Garrett states, always underestimates reliability as compared with the split-half technique and the Spearman-Brown formula, but it provides a minimum estimate of reliability.[15]

The degree to which it is known that a test measures what it is designed to measure is an index of the validity of the test.[16] Empirical validation necessitates comparing test results with a criterion known to measure some characteristic closely related to the content of the test. Finding satisfactory criterion measures is a great obstacle to accurate evaluation of the validity of tests.[17] Test constructors have had to be satisfied with criteria "each of which has some degree of adequacy less than complete, and some degree of practicality."[18] In achievement test construction, the criteria usually used for validation purposes are school ratings or gradings in the subject area of the test. Working with a group of 300 students would require that a number of teachers make the necessary gradings. These measures in themselves are inaccurate but in this case the added problem of variation of gradings among teachers would also be present. To avoid these difficulties, it was felt that standard gradings from the Department of Education would give much more satisfactory results for testing the validity of the Edmonton Test of Equivalence.

## ITEM ANALYSIS

The care with which the items of a test have been chosen increases the validity of the instrument. Two statistical aspects of item analysis are the difficulty level and the discriminating power of the items. Expressed as a percentage, the proportion of the group solving an item correctly gives a measure of item difficulty. The percentage order of difficulty can be scaled in terms of standard deviation, if the assumption of normal distribution of the trait is made.[19] Davis, using the percentage of success of the highest and lowest 27% of the sample, corrected for chance, has devised an Item Analysis Chart for determining the difficulty indices of items.[20]

The power of an item to discriminate high-scoring individuals is termed the discrimination index of the item. This power of discrimination may be in terms of total score or for ease of computation against dichotomized groups.

The item analysis of the Edmonton Test of Equivalence was done by the Davis Technique.

## SUBTEST SCORES

A test made up of a series of subtests gives rise to the question of the possible diagnostic value of these subscores. Intercorrelation of subtests may indicate that they possess a common element or that they have little in common and measure different abilities.[21] To yield a meaningful total score the subtests usually have a great deal in common but this common factor interferes with diagnostic value. In addition to what the subtests measure,

the consistency with which they measure this quality must also be determined. The reliability of the total score does not in itself establish the reliability of the subtests. The subtests must be correlated, usually through equivalent forms, to establish independent reliability.

By the product-moment method the reliability of each of the subtests of the alternate forms was found. The intercorrelations of the four subtests of each form were also determined by the same technique.

## STATISTICAL PROCEDURES

In the analysis of the 300 scores, the plan of procedure outlined below was followed.

1. The reliability of the Edmonton Test of Equivalence was computed by two procedures:

   a. the product-moment coefficient of correlation between Forms A and B,

   b. the Froelich approximation of the Kuder-Richardson formula for the method of rational equivalence.

2. The validity of the Edmonton Test of Equivalence was determined in terms of three criteria:

   a. Department of Education marks in Grade IX mathematics,

   b. Department of Education marks in the Grade IX General Test,

   c. Department of Education total score on the Grade IX final examinations in all subjects.

3. An item analysis of the Edmonton Test of Equivalence was made by the Davis technique.

On the basis of the percentage of success (corrected for chance) of the highest and lowest 27% of the 300 test scores for each form, the discrimination and difficulty indices were determined for each item.

4. An analysis of the subtests of the Edmonton Test of Equivalence was made.

a. The reliability of each subtest was determined by correlating Form A and Form B subtest scores by the product-moment method.

b. To measure the degree of uniqueness of each scale the intercorrelations of the subtests were found by the product-moment coefficient of correlation.

5. The practice effect of taking the alternate form of the Edmonton Test of Equivalence was measured by:

a. testing the reliability of the differences between the means and between the standard deviations of Groups I and II to determine whether significant gains were made,

b. determining the average mean gain for the two forms.

6. The two forms of the Edmonton Test of Equivalence were compared.

a. The reliability of the differences between the means and between the standard deviations of the distributions of scores on Form A and Form B were tested for significance.

b. To measure the divergence from normalcy of the distribution of difficulty of the items, the Chi-square test was applied.

c. The distribution of scores on Form A was tested for departure from normalcy by testing the reliability of the measure of skewness.

d. The probable causes for departure from normalcy of the distribution of scores on Form B were discussed.

## CHAPTER V

## THE RELIABILITY AND VALIDITY OF THE EDMONTON TEST OF EQUIVALENCE

### RELIABILITY

The reliability of the Edmonton Test of Equivalence in Mathematics was determined by two of the accepted measures of reliability. By means of the product-moment coefficient of correlation, Form A and Form B were correlated. As a second estimate of reliability the Froelich adaptation of the Richardson-Kuder formula of rational equivalence was applied.

The distributions of the corresponding test scores for the 300 students on Forms A and B of the Edmonton Test of Equivalence are shown in Table III.

TABLE III : CALCULATIONS OF MEANS AND STANDARD DEVIATIONS FOR 300 SCORES ON FORMS A AND B OF THE EDMONTON TEST OF EQUIVALENCE IN MATHEMATICS FOR GRADE IX

| FORM A | | | | | FORM B | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SCORES | f | $x'$ | $fx'$ | $fx'^2$ | SCORES | f | $x'$ | $fx'$ | $fx'^2$ |
| 60-65 | 2 | 6 | 12 | 72 | 60-65 | 3 | 7 | 21 | 147 |
| 55-60 | 4 | 5 | 20 | 100 | 55-60 | 3 | 6 | 18 | 108 |
| 50-55 | 19 | 4 | 76 | 304 | 50-55 | 7 | 5 | 35 | 175 |
| 45-50 | 15 | 3 | 45 | 135 | 45-50 | 19 | 4 | 76 | 304 |
| 40-45 | 30 | 2 | 60 | 120 | 40-45 | 56 | 3 | 168 | 504 |
| 35-40 | 53 | 1 | 53 | 53 | 35-40 | 33 | 2 | 66 | 132 |
| 30-35 | 50 | 0 | 0 | 0 | 30-35 | 30 | 1 | 30 | 30 |
| 25-30 | 48 | -1 | -48 | 48 | 25-30 | 54 | 0 | 0 | 0 |
| 20-25 | 46 | -2 | -92 | 184 | 20-25 | 54 | -1 | -54 | 54 |
| 15-20 | 24 | -3 | -72 | 216 | 15-20 | 32 | -2 | -64 | 128 |
| 10-15 | 8 | -4 | -32 | 128 | 10-15 | 8 | -3 | -74 | 72 |
| 5-10 | 1 | -5 | -5 | 25 | 5-10 | 1 | -4 | -4 | 16 |
| TOTAL | 300 | | 17 | 1385 | TOTAL | 300 | | 268 | 1670 |

M = 32.78 M = 31.95

SD = 10.75 SD = 10.95

Figure I in Appendix B is the scattergram of the distributions of the scores for Forms A and B. The computation of the product-moment coefficient of correlation gave a result of r = 0.84. Since the distributions of scores on the two forms as shown in Table III indicate that Form B has a bimodal distribution, interpretation of the result of correlation from the product-moment formula must be cautiously done. Correlations based on alternate forms necessitate the pairing of scores on the two forms, and bimodality of one of the forms suggests a lack of association between the pairs which might result in lowering the coefficient of correlation.

Since the study is restricted in its use of reliability techniques by the element of speed necessary in the administration of the tests, Froelich's adaptation of the Richardson-Kuder formula for measuring reliability by the method of rational equivalence, was used to give an estimate of the degree of reliability of each test. The formula devised by Froelich is:

$$r_{11} = \frac{n\sigma_x^2 - M(n-M)}{\sigma_x^2 (n-1)} \qquad (22)$$

where

$r_{11}$ = reliability of the whole test;

$n$ = number of items in the test;

$\sigma_x$ = S.D. of the test scores;

$M$ = the mean of the test scores.

The formula yielded a reliability coefficient of r = 0.86 for Form A and r = 0.87 for Form B.

Comparing the results of the two independent measures of reliability, it was noted that Froelich's formula gave a higher degree of correlation than did the product-moment method. Garrett states that the two measures "are not strictly comparable for determining the reliability of test scores." The method of rational equivalence provides "an estimate of the internal consistency of the tests rather than an estimate of the dependability of test scores."[23] It would thus appear that the Edmonton Test of Equivalence has a higher degree of internal consistency than of total score reliability.

## VALIDITY

The administration of final examinations to Grade IX students by the Department of Education provided convenient data for determining measures of validity of the Edmonton Test of Equivalence in Mathematics. Perhaps more has been done in the way of testing validity than is warranted, but lack of data is usually such a drawback to statistical research that it was felt that full use should be made of the data which was at hand. The criteria used were three scores obtained from the Department of Education Examinations Branch; marks on the Grade IX mathematics final; marks on the Grade IX General Test; and total score on the Grade IX finals. The criteria, in addition to availability, have the further advantage of being carefully controlled gradings achieved under the close supervision of the Department of Education. The unreliability of teachers' gradings was the very cause of the growth

of the measurement movement, and by avoiding such gradings as criteria in this study, there should be more assurance of validity of results. The three criteria were chosen in the interest of teachers who would wish to know if the tests measure achievement in mathematics, whether under-achievement in mathematics can be assumed by comparison of I.Q's with mathematics marks and whether mathematics marks give an indication of success in the Grade IX school year.

Table I in Appendix C shows the corresponding scores for each of the two forms of the test along with the scores for each of the three criterion measures for the 300 Grade IX students. The results of the computation of the product-moment coefficients of correlation are shown in Table IV.

TABLE IV : RESULTS OF CORRELATING FORMS A AND B OF THE EDMONTON TEST OF EQUIVALENCE WITH THE THREE CRITERIA

| | Form A | Form B |
|---|---|---|
| Grade IX Departmental Mathematics Finals | 0.77 | 0.76 |
| Grade IX Departmental General Test | 0.73 | 0.67 |
| Total Score on Grade IX Departmental Finals | 0.60 | 0.53 |

The results of Table IV would indicate that the test is not highly valid as an instrument for measuring achievement in Grade IX mathematics, and still less valid in measuring achievement in the Grade IX departmental examinations. The low coefficient of correlation between the General Test (Henmon-Nelson Intelligence Test, Level 7-9, Form C) and the Edmonton Test of Equivalence in Mathematics would indicate that this measure of mathematical equivalence and measures of intelligence do not have too great a relationship. Yet interpretation of results is subject to precaution, for Cronback states, "In interpreting any correlation coefficient, the range of the group studied must be considered. The correlation is smaller in a selected group than in a group containing a wider range of ability."[24] It must be noted that this study used a sample restricted in grade level to Grade IX students and those being drawn only from the Edmonton Separate School system.

# CHAPTER VI

## ITEM ANALYSIS OF THE EDMONTON TEST OF EQUIVALENCE IN MATHEMATICS

In recent years many techniques of item analysis have been devised. Of these perhaps the most satisfactory is the one advanced by Davis which will be used in this study. The practical advantage of using item analysis has been widely recognized as a means of determining the difficulty level and the discriminating power of items. Designed for maximum convenience in test construction, the Davis chart yields both a difficulty index and a discrimination index at the same reading.

> The difficulty index, which is the bottom value in each cell in the chart, provides a numerical indication of the difficulty level of each individual item relative to other items administered to the same sample of testees. The discrimination index, which is the top value in each cell in the chart, provides a numerical indication of the amount of discriminating ability of each individual item with respect to a designated criterion variable, often the total score on the test in which the item is included.[25]

### THE DAVIS DIFFICULTY AND DISCRIMINATION INDICES

"The difficulty of an item may be defined as the proportion of a certain sample of testees that marks the item correctly, or it may be defined as the proportion of a certain sample of testees that actually knows the answer to an item."[26] Since a certain proportion of the testees may mark the correct answer by chance, a correction may be employed. Though some feel that such devices over-correct for chance, Davis feels that such correction should be made. The formula Davis suggests be used is:

$$P = \frac{R - \frac{W}{K-1}}{N - NR}$$

(27)

where: R = the number of testees that answer the item correctly,
W = the number of testees that answer the item incorrectly,
K = the number of choices in the item,
N = the number of testees in the sample,
NR = the number of testees in the sample that do not reach the item in the time limit.

To calculate the difficulty of an item on a test from the responses of the entire sample involves extremely laborious computation. Kelly has shown that the difficulty level of items, based only on responses of the top and bottom 27% of the sample, reduces clerical labor almost by half without impairing results. Davis bases his estimate of the difficulty of an item on these extreme groups by averaging the percentages of success of these two groups, transforming this proportion of success into standard deviation units, multiplying each standard score by a constant so chosen as to make the largest 49, and as a final step, adding 50 to each score. This results in difficulty indices in the Davis Item Analysis Chart ranging from 1 to 99 only.

The discrimination index of items is also based on the difficulty of the items for the highest and lowest 27% of the sample. Flanagan prepared tables of correlation coefficients corresponding to the possible percentages of success in the upper and lower groups. These correlation coefficients are estimates of the product-moment correlation between item success and test score. The fact that the unit on the scale does

not have the same significance as one goes from small to large values, has been overcome by Davis by converting Flanagan's correlation values into Fisher's z- values and multiplying by a constant such that the index becomes 100 when 99% of one group succeeds with the item and only 1% of the other group succeeds.

## THE COMPUTATIONAL PROCEDURE

After the Edmonton Test of Equivalence in Mathematics had been administered, the test papers were marked and the papers for each form arranged in order of rank with respect to total score. The highest and the lowest 27% of the papers (81 papers in each extreme group) for each form, were removed and tabulation made of the choice of answer to each item. The number leaving the item unanswered and those who failed to reach the item were also marked. The results of these tabulations are shown in Tables V, VI, VII, and VIII.

TABLE V : TABULATION OF RESPONSES ON THE THIRTY-FIVE MULTIPLE-CHOICE ITEMS, PART I OF FORM A WITH COMPUTATION BASED ON 27% SCORING HIGHEST AND LOWEST

| Item No. | 27% Scoring Highest | | | | | | | | 27% Scoring Lowest | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | | Tally of Responses | | | | | | Total | | Tally of responses | | | | | |
| | C | W | A | B | C | D | R | NR | C | W | A | B | C | D | R | NR |
| 1 | 79 | 2 | | 1 | | 1 | | | 74 | 6 | 3 | | 2 | 1 | 1 | |
| 2 | 78 | 1 | | 1 | | | 2 | | 55 | 24 | 5 | 9 | | 10 | 2 | |
| 3 | 80 | 1 | 1 | | | | | | 62 | 18 | 2 | 10 | 6 | | 1 | |
| 4 | 73 | 8 | 4 | 4 | | | | | 48 | 32 | | 17 | 4 | 11 | 1 | |
| 5 | 78 | 2 | | | | 2 | 1 | | 51 | 28 | 4 | | 14 | 10 | 2 | |
| 6 | 72 | 9 | 2 | | 5 | 2 | | | 36 | 42 | 4 | 20 | 18 | | 3 | |
| 7 | 80 | 1 | | | 1 | | | | 50 | 31 | | 6 | 11 | 14 | | |
| 8 | 78 | 3 | 2 | | 1 | | | | 52 | 26 | 9 | 10 | 7 | | 3 | |
| 9 | 80 | 1 | | | 1 | | | | 32 | 45 | 9 | 24 | 12 | | 4 | |
| 10 | 61 | 17 | | 3 | 3 | 11 | 3 | | 44 | 35 | | 25 | 6 | 4 | 2 | |
| 11 | 76 | 5 | 1 | 2 | | 2 | | | 64 | 16 | 8 | 6 | | 2 | 1 | |
| 12 | 62 | 18 | 2 | | 5 | 11 | 1 | | 33 | 45 | 9 | 32 | 4 | | 3 | |
| 13 | 75 | 4 | 1 | | 2 | 1 | 2 | | 26 | 48 | 17 | 17 | 14 | | 7 | |
| 14 | 73 | 8 | 1 | 5 | | 2 | | | 35 | 40 | 5 | 3 | | 32 | 6 | |
| 15 | 58 | 22 | 6 | | 13 | 3 | 1 | | 33 | 41 | 7 | 9 | 25 | | 7 | |
| 16 | 73 | 6 | 2 | 1 | 3 | | 2 | | 53 | 28 | | 7 | 16 | 5 | | |
| 17 | 69 | 12 | 4 | 7 | 1 | | | | 7 | 69 | | 19 | 47 | 3 | 5 | |
| 18 | 51 | 28 | | 5 | 4 | 19 | 2 | | 16 | 57 | | 32 | 12 | 13 | 7 | 1 |
| 19 | 71 | 9 | | | | 9 | 1 | | 43 | 31 | 5 | | 18 | 8 | 6 | 1 |
| 20 | 69 | 12 | | 6 | 2 | 4 | | | 32 | 34 | 5 | 13 | | 16 | 13 | 2 |
| 21 | 42 | 37 | 8 | | 3 | 26 | 2 | | 9 | 65 | 19 | 3 | 43 | | 4 | 3 |
| 22 | 63 | 17 | 16 | | 1 | | 1 | | 34 | 30 | 2 | | 18 | 10 | 14 | 3 |
| 23 | 58 | 19 | 8 | 4 | 7 | | 4 | | 13 | 51 | | 17 | 20 | 14 | 14 | 3 |
| 24 | 40 | 41 | 1 | | 11 | 29 | | | 7 | 63 | 46 | 1 | 16 | | 8 | 3 |
| 25 | 62 | 19 | | 3 | 8 | 8 | | | 26 | 47 | 28 | | 17 | 2 | 5 | 3 |
| 26 | 39 | 41 | 13 | | 14 | 14 | | 1 | 20 | 44 | 4 | 14 | 26 | | 12 | 5 |
| 27 | 46 | 27 | | 10 | 6 | 12 | 5 | 2 | 13 | 43 | | 4 | 14 | 25 | 18 | 7 |
| 28 | 66 | 11 | 1 | | 2 | 8 | 2 | 2 | 20 | 47 | 6 | 31 | 10 | | 7 | 7 |
| 29 | 36 | 42 | 2 | 34 | | 6 | 1 | 2 | 8 | 52 | 35 | 11 | | 6 | 10 | 11 |
| 30 | 38 | 37 | 19 | | 9 | 9 | 3 | 3 | 16 | 39 | 9 | 14 | 15 | | 13 | 13 |
| 31 | 51 | 14 | 6 | | 6 | 2 | 10 | 6 | 16 | 35 | 5 | 12 | 18 | | 9 | 21 |
| 32 | 40 | 30 | 1 | 9 | 12 | 9 | 5 | 6 | 12 | 39 | 6 | 12 | | 21 | 7 | 23 |
| 33 | 39 | 33 | 4 | | 29 | | 1 | 8 | 2 | 53 | 1 | 10 | 41 | | 1 | 25 |
| 34 | 53 | 11 | 1 | 3 | 7 | 1 | 4 | 13 | 14 | 29 | 4 | 10 | | 15 | 5 | 33 |
| 35 | 43 | 18 | 4 | 7 | 2 | 6 | 5 | 15 | 19 | 27 | | 5 | 14 | 8 | | 35 |

C = correct responses.
W = incorrect responses.
A,B,C,D, = choice of response.
R = number of testees reading the item but failing to mark a response.
NR = number of testees failing to reach the item in the time limit.

TABLE VI : TABULATION OF RESPONSES ON THE THIRTY-FIVE MULTIPLE-CHOICE ITEMS, PART I OF FORM B WITH COMPUTATION BASED ON 27% SCORING HIGHEST AND LOWEST

| Item No. | 27% Scoring Highest | | | | | | | | 27% Scoring Lowest | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | | Tally of Responses | | | | | | Total | | Tally of responses | | | | | |
| | C | W | A | B | C | D | R | NR | C | W | A | B | C | D | R | NR |
| 1 | 79 | 2 | | | 2 | | | | 72 | 9 | 2 | 7 | | | | |
| 2 | 70 | 10 | | 4 | | 6 | 1 | | 70 | 9 | 3 | 2 | | 4 | 2 | |
| 3 | 79 | 2 | | 1 | 1 | | | | 47 | 30 | 3 | | 12 | 15 | 4 | |
| 4 | 76 | 5 | | 2 | 1 | 2 | | | 45 | 34 | 15 | 12 | 7 | | 2 | |
| 5 | 78 | 2 | 2 | | | | 1 | | 58 | 16 | | 7 | 5 | 4 | 7 | |
| 6 | 76 | 4 | | 4 | | | 1 | | 25 | 54 | 9 | | 12 | 33 | 2 | |
| 7 | 79 | 2 | 1 | 1 | | 1 | | | 64 | 15 | 10 | 3 | 2 | | 2 | |
| 8 | 81 | | | | | | | | 54 | 25 | 1 | | 10 | 14 | 2 | |
| 9 | 70 | 10 | 3 | | 6 | 1 | 1 | | 42 | 39 | 9 | 10 | 19 | 2 | | |
| 10 | 58 | 21 | | 17 | 2 | 2 | 2 | | 43 | 34 | | 8 | 11 | 15 | 4 | |
| 11 | 81 | | | | | | | | 54 | 25 | | 18 | | 7 | 2 | |
| 12 | 75 | 6 | 1 | 3 | 1 | 1 | | | 12 | 64 | 3 | | 19 | 42 | 5 | |
| 13 | 68 | 13 | 4 | 8 | 1 | | | | 26 | 51 | 2 | | 22 | 28 | 2 | |
| 14 | 70 | 10 | 4 | 1 | | 5 | 1 | | 37 | 34 | 1 | 27 | | 6 | 9 | 1 |
| 15 | 70 | 10 | 2 | | 8 | | 1 | | 12 | 65 | 15 | | 27 | 23 | 3 | 1 |
| 16 | 79 | 2 | | 1 | | 1 | | | 32 | 47 | 23 | 10 | 14 | | 1 | 1 |
| 17 | 22 | 57 | | 9 | 48 | | 2 | | 37 | 36 | 10 | 12 | 14 | | 6 | 2 |
| 18 | 51 | 29 | | 11 | 11 | 7 | 1 | | 10 | 63 | | 10 | 24 | 29 | 5 | 3 |
| 19 | 63 | 16 | | | 12 | 4 | 2 | | 44 | 28 | 5 | 3 | | 20 | 6 | 3 |
| 20 | 77 | 4 | | 3 | 1 | | | | 16 | 49 | | 16 | 10 | 23 | 13 | 3 |
| 21 | 41 | 38 | 6 | 1 | 31 | | 2 | | 7 | 67 | 14 | | 7 | 46 | 3 | 4 |
| 22 | 70 | 8 | 2 | | 4 | 2 | 3 | | 21 | 52 | 32 | 5 | | 15 | 4 | 4 |
| 23 | 47 | 30 | | 11 | 13 | 6 | 4 | | 30 | 42 | 15 | 8 | 17 | 2 | 5 | 4 |
| 24 | 34 | 46 | 36 | | 10 | | 1 | | 8 | 69 | 1 | | 18 | 50 | | 4 |
| 25 | 74 | 7 | 3 | | 3 | 1 | | | 17 | 57 | | 12 | 17 | 28 | 2 | 5 |
| 26 | 41 | 39 | 6 | 15 | 18 | | 1 | | 15 | 47 | 6 | | 20 | 21 | 13 | 6 |
| 27 | 37 | 40 | | 11 | 9 | 20 | 4 | | 10 | 53 | | 12 | 5 | 36 | 12 | 6 |
| 28 | 59 | 20 | 1 | 15 | 4 | | 2 | | 23 | 50 | 3 | | 11 | 36 | 2 | 6 |
| 29 | 47 | 31 | 25 | 2 | | 4 | 3 | | 7 | 61 | 11 | 42 | | 8 | 5 | 8 |
| 30 | 49 | 28 | 8 | 12 | 8 | | 3 | 1 | 20 | 44 | 15 | | 12 | 17 | 6 | 11 |
| 31 | 49 | 23 | 4 | 10 | 9 | | 7 | 2 | 22 | 37 | 12 | | 13 | 12 | 8 | 14 |
| 32 | 45 | 32 | 8 | 19 | | 5 | 2 | 2 | 5 | 52 | | 13 | 19 | 20 | 7 | 17 |
| 33 | 20 | 53 | | 8 | 45 | | 2 | 6 | 19 | 43 | 8 | | 32 | 3 | 2 | 17 |
| 34 | 26 | 36 | 2 | 16 | | 18 | 6 | 13 | 28 | 23 | 2 | 12 | 9 | | 8 | 22 |
| 35 | 50 | 17 | | 6 | 5 | 6 | | 14 | 9 | 44 | 6 | 29 | | 8 | 1 | 27 |

C = correct responses.
W = incorrect responses.
A, B, C, D, = choice of response.
R = number of testees reading the item but failing to mark a response.
NR = number of testees failing to reach the item in the time limit.

TABLE VII : TABULATION OF RESPONSES ON THE THIRTY-FOUR COMPLETION TYPE ITEMS, PART II OF FORM A WITH COMPUTATION BASED ON 27% SCORING HIGHEST AND LOWEST

| Item No. | 27% Scoring Highest | | | | 27% Scoring Lowest | | | |
|---|---|---|---|---|---|---|---|---|
| | Right | Wrong | R[1] | NR[2] | Right | Wrong | R[1] | NR[2] |
| 1 | 80 | 1 | | | 73 | 7 | 1 | |
| 2 | 73 | 8 | | | 41 | 30 | 10 | |
| 3 | 63 | 16 | 2 | | 35 | 36 | 10 | |
| 4 | 68 | 13 | | | 32 | 45 | 4 | |
| 5 | 62 | 16 | 3 | | 40 | 30 | 11 | |
| 6 | 60 | 19 | 2 | | 33 | 46 | 2 | |
| 7 | 19 | 60 | 2 | | | 77 | 4 | |
| 8 | 73 | 8 | | | 45 | 34 | 2 | |
| 9 | 48 | 33 | | | 11 | 65 | 5 | |
| 10 | 45 | 35 | 1 | | 12 | 64 | 5 | |
| 11 | 62 | 18 | 1 | | 16 | 52 | 13 | |
| 12 | 74 | 6 | 1 | | 27 | 43 | 11 | |
| 13 | 66 | 12 | 3 | | 18 | 54 | 9 | |
| 14 | 42 | 33 | 6 | | 3 | 72 | 6 | |
| 15 | 24 | 52 | 5 | | 2 | 59 | 20 | |
| 16 | 47 | 33 | 1 | | 11 | 65 | 5 | |
| 17 | 18 | 57 | 6 | | | 71 | 10 | |
| 18 | 56 | 25 | | | 19 | 57 | 5 | |
| 19 | 46 | 27 | 8 | | 12 | 52 | 17 | |
| 20 | 68 | 12 | 1 | | 23 | 50 | 8 | |
| 21 | 66 | 15 | | | 9 | 59 | 13 | |
| 22 | 57 | 23 | 1 | | 8 | 57 | 16 | |
| 23 | 26 | 47 | 8 | | 1 | 65 | 14 | 1 |
| 24 | 61 | 18 | 2 | | 12 | 64 | 4 | 1 |
| 25 | 56 | 22 | 3 | | 2 | 60 | 16 | 3 |
| 26 | 45 | 28 | 8 | | 11 | 57 | 10 | 3 |
| 27 | 28 | 42 | 11 | | 6 | 60 | 12 | 3 |
| 28 | 40 | 40 | 1 | | 12 | 64 | 2 | 3 |
| 29 | 31 | 34 | 14 | 2 | 1 | 50 | 24 | 6 |
| 30 | 8 | 56 | 15 | 2 | | 50 | 25 | 6 |
| 31 | 36 | 29 | 14 | 2 | 20 | 44 | 11 | 6 |
| 32 | 5 | 65 | 9 | 2 | 1 | 69 | 4 | 7 |
| 33 | 4 | 61 | 13 | 3 | | 69 | 3 | 9 |
| 34 | | | | | | | | |
| 35 | 16 | 48 | 2 | 15 | 4 | 58 | 2 | 17 |

1. R = the number of testees that read the item but did not mark a response.
2. NR = the number of testees in the sample that did not reach the item in the time limit.

TABLE VIII : TABULATION OF RESPONSES ON THE THIRTY-FOUR COMPLETION TYPE ITEMS, PART II OF FORM B WITH COMPUTATION BASED ON 27% SCORING HIGHEST AND LOWEST

| Item No. | 27% Scoring Highest | | | | 27% Scoring Lowest | | | |
|---|---|---|---|---|---|---|---|---|
| | Right | Wrong | R[1] | NR[2] | Right | Wrong | R[1] | NR[2] |
| 1 | 81 | | | | 80 | | 1 | |
| 2 | 66 | 13 | 2 | | 33 | 42 | 6 | |
| 3 | 49 | 32 | | | 33 | 43 | 5 | |
| 4 | 73 | 8 | | | 47 | 32 | 2 | |
| 5 | 25 | 49 | 7 | | 1 | 61 | 19 | |
| 6 | 66 | 14 | 1 | | 18 | 62 | 1 | |
| 7 | 11 | 53 | 17 | | 1 | 62 | 18 | |
| 8 | 58 | 23 | | | 39 | 38 | 4 | |
| 9 | 57 | 24 | | | 9 | 59 | 13 | |
| 10 | 56 | 24 | 1 | | 15 | 63 | 3 | |
| 11 | 46 | 34 | 1 | | 3 | 72 | 6 | |
| 12 | 72 | 9 | | | 31 | 41 | 9 | |
| 13 | 58 | 21 | 2 | | 7 | 62 | 12 | |
| 14 | 48 | 28 | 5 | | 1 | 70 | 9 | 1 |
| 15 | 26 | 49 | 6 | | 1 | 58 | 21 | 1 |
| 16 | 35 | 42 | 4 | | 3 | 62 | 15 | 1 |
| 17 | 36 | 39 | 6 | | 6 | 63 | 11 | 1 |
| 18 | 55 | 23 | 3 | | 16 | 57 | 5 | 1 |
| 19 | 46 | 25 | 10 | | 8 | 55 | 17 | 1 |
| 20 | 71 | 10 | | | 12 | 56 | 12 | 1 |
| 21 | 70 | 11 | | | 9 | 63 | 7 | 2 |
| 22 | 54 | 27 | | | 7 | 59 | 13 | 2 |
| 23 | 34 | 42 | 5 | | 2 | 54 | 22 | 3 |
| 24 | 63 | 15 | 3 | | 5 | 65 | 8 | 3 |
| 25 | 70 | 6 | 5 | | 10 | 50 | 15 | 6 |
| 26 | 50 | 25 | 6 | | 24 | 35 | 14 | 8 |
| 27 | 35 | 31 | 15 | | 1 | 57 | 13 | 10 |
| 28 | 50 | 28 | 3 | | 10 | 56 | 5 | 10 |
| 29 | 34 | 39 | 8 | | | 45 | 25 | 11 |
| 30 | 1 | 73 | 6 | 1 | | 56 | 14 | 11 |
| 31 | 43 | 27 | 5 | 6 | 23 | 35 | 11 | 12 |
| 32 | 8 | 58 | 6 | 9 | | 64 | 4 | 13 |
| 33 | 17 | 45 | 7 | 12 | 1 | 57 | 7 | 16 |
| 34 | | | | | | | | |
| 35 | 5 | 51 | | 25 | | 57 | | 24 |

1. R = the number of testees that read the item but did not mark a response.
2. NR = the number of testees in the sample that did not reach the item in the time limit.

From the data of Tables V, VI, VII and VIII, the proportions of success in the highest and lowest 27% of the sample were computed by means of the formulas:

$$P = \frac{R_H - \frac{W_H}{K-1}}{N_H - NR_H} \qquad P = \frac{R_L - \frac{W_L}{K-1}}{N_L - NR_L} \tag{28}$$

where:

$N_H$ = the number of testees in the highest 27%,
$R_H$ = the number of testees in the highest 27% that answer the item correctly,
$W_H$ = the number of testees in the highest 27% that answer the item incorrectly,
$NR_H$ = the number of testees in the highest 27% that do not reach the item in the time limit,
K = the number of choices in the item.

$N_L$ = the number of testees in the lowest 27%,
$R_L$ = the number of testees in the lowest 27% that answer the item correctly,
$W_L$ = the number of testees in the lowest 27% that answer the item incorrectly,
$NR_L$ = the number of testees in the lowest 27% that do not reach the item in the time limit,
K = the number of choices in the item.

Discrimination and difficulty indices were read simultaneously by entering the percentages of success in the Item Analysis Chart. In many instances, as shown in Tables IX and X, where the two proportions used to enter the chart were different, there was no straightforward way of using the Item Analysis Chart. Davis has overcome this limitation by devising a table which provides corrected percentages for entering the chart when the percentages of success in the lowest 27% of the sample is 0 or negative.[29] If the percentage of success in the highest 27% is above 99%, the percent used to enter the chart must first be altered by use of the table provided by Davis.[30]

Tables IX and X provide a summary of difficulty and 'discrimination' indices for all items of the Edmonton Test of Equivalence in Mathematics, as determined by the Davis technique .

TABLE IX : SUMMARY OF DISCRIMINATION AND DIFFICULTY INDICES FOR THIRTY-FIVE MULTIPLE CHOICE ITEMS OBTAINED FROM THE DAVIS ITEM ANALYSIS CHART

| | FORM A, PART I | | | | FORM B, PART I | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | % of Success of Highest 27% | % of Success of Lowest 27% | Discrimination Index | Difficulty Index | % of Success of Highest 27% | % of Success of Lowest 27% | Discrimination Index | Difficulty Index |
| 1 | 97 | 85 | 21 | 78 | 97 | 89 | 16 | 81 |
| 2 | 96 | 83 | 20 | 77 | 82 | 58 | 17 | 61 |
| 3 | 98 | 46 | 52 | 62 | 97 | 69 | 34 | 70 |
| 4 | 87 | 42 | 33 | 58 | 92 | 46 | 37 | 60 |
| 5 | 95 | 65 | 31 | 68 | 95 | 51 | 40 | 63 |
| 6 | 85 | 9 | 58 | 48 | 92 | 27 | 49 | 55 |
| 7 | 98 | 73 | 35 | 73 | 97 | 49 | 47 | 63 |
| 8 | 95 | 56 | 37 | 65 | 100 | 53 | 54 | 65 |
| 9 | 98 | 36 | 57 | 59 | 82 | 21 | 43 | 51 |
| 10 | 68 | 39 | 19 | 52 | 63 | 40 | 14 | 51 |
| 11 | 92 | 56 | 31 | 63 | 100 | 72 | 43 | 72 |
| 12 | 69 | -12 | 67 | 42 | 90 | 22 | 50 | 53 |
| 13 | 91 | 12 | 61 | 51 | 79 | 12 | 49 | 48 |
| 14 | 87 | 32 | 39 | 55 | 82 | 27 | 37 | 53 |
| 15 | 63 | -12 | 37 | 44 | 82 | 24 | 40 | 52 |
| 16 | 88 | 20 | 49 | 52 | 97 | 54 | 44 | 65 |
| 17 | 80 | 32 | 32 | 53 | 4 | -20 | 14 | 9 |
| 18 | 51 | -14 | 56 | 37 | 51 | - 4 | 56 | 37 |
| 19 | 84 | 44 | 28 | 58 | 71 | 41 | 19 | 53 |
| 20 | 80 | -42 | 74 | 45 | 93 | 26 | 52 | 55 |
| 21 | 37 | -20 | 49 | 32 | 35 | -16 | 48 | 31 |
| 22 | 71 | 5 | 53 | 44 | 83 | 31 | 34 | 54 |
| 23 | 64 | 21 | 29 | 46 | 46 | - 5 | 53 | 35 |
| 24 | 33 | -19 | 46 | 30 | 23 | -18 | 38 | 26 |
| 25 | 69 | -26 | 67 | 42 | 88 | 13 | 55 | 51 |
| 26 | 32 | -88 | 45 | 30 | 35 | 7 | 27 | 33 |
| 27 | 46 | -10 | 53 | 35 | 29 | - 2 | 44 | 29 |
| 28 | 79 | 8 | 54 | 47 | 65 | 6 | 48 | 42 |
| 29 | 28 | -18 | 43 | 28 | 45 | -13 | 53 | 35 |
| 30 | 33 | 8 | 24 | 33 | 50 | 5 | 41 | 38 |
| 31 | 62 | 14 | 34 | 44 | 52 | 7 | 38 | 39 |
| 32 | 38 | -19 | 49 | 32 | 43 | - 2 | 52 | 34 |
| 33 | 38 | 7 | 29 | 30 | 3 | -28 | 11 | 7 |
| 34 | 71 | 34 | 24 | 52 | 22 | 9 | 14 | 29 |
| 35 | 52 | -10 | 56 | 37 | 65 | 21 | 30 | 46 |

TABLE X : SUMMARY OF DISCRIMINATION AND DIFFICULTY INDICES FOR THIRTY-FOUR COMPLETION TYPE ITEMS OBTAINED FROM DAVIS ITEM ANALYSIS CHART

| | FORM A, PART II | | | | FORM B, PART II | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | % of Success of Highest 27% | % of Success of Lowest 27% | Discrimination Index | Difficulty Index | % of Success of Highest 27% | % of Success of Lowest 27% | Discrimination Index | Difficulty Index |
| 1 | 99 | 90 | 25 | 84 | 100 | 99 | 0 | 99 |
| 2 | 90 | 51 | 31 | 61 | 81 | 41 | 28 | 55 |
| 3 | 78 | 43 | 24 | 56 | 61 | 41 | 12 | 51 |
| 4 | 84 | 40 | 31 | 56 | 90 | 58 | 26 | 63 |
| 5 | 77 | 49 | 19 | 57 | 31 | 1 | 44 | 29 |
| 6 | 74 | 41 | 22 | 54 | 82 | 22 | 42 | 51 |
| 7 | 23 | 0 | 35 | 26 | 14 | 1 | 30 | 20 |
| 8 | 90 | 56 | 28 | 63 | 72 | 48 | 16 | 55 |
| 9 | 59 | 14 | 32 | 43 | 70 | 11 | 44 | 45 |
| 10 | 56 | 15 | 29 | 42 | 69 | 19 | 34 | 47 |
| 11 | 77 | 20 | 39 | 49 | 57 | 4 | 47 | 40 |
| 12 | 91 | 33 | 44 | 56 | 89 | 38 | 38 | 58 |
| 13 | 81 | 22 | 41 | 51 | 72 | 9 | 47 | 45 |
| 14 | 52 | 4 | 44 | 38 | 59 | 1 | 61 | 39 |
| 15 | 30 | 3 | 32 | 29 | 32 | 1 | 45 | 30 |
| 16 | 58 | 14 | 31 | 42 | 43 | 4 | 39 | 35 |
| 17 | 22 | 0 | 37 | 25 | 45 | 8 | 32 | 37 |
| 18 | 69 | 23 | 31 | 48 | 68 | 20 | 32 | 47 |
| 19 | 57 | 15 | 29 | 42 | 57 | 10 | 36 | 41 |
| 20 | 84 | 28 | 53 | 37 | 88 | 15 | 53 | 51 |
| 21 | 81 | 11 | 52 | 48 | 86 | 11 | 56 | 49 |
| 22 | 70 | 10 | 45 | 45 | 67 | 9 | 44 | 44 |
| 23 | 32 | 1 | 45 | 30 | 42 | 3 | 42 | 34 |
| 24 | 75 | 15 | 42 | 47 | 78 | 6 | 56 | 46 |
| 25 | 69 | 3 | 58 | 42 | 86 | 13 | 53 | 50 |
| 26 | 56 | 14 | 30 | 42 | 62 | 33 | 19 | 49 |
| 27 | 35 | 8 | 25 | 34 | 43 | 1 | 52 | 34 |
| 28 | 50 | 15 | 24 | 41 | 62 | 14 | 34 | 44 |
| 29 | 39 | 1 | 49 | 32 | 42 | 0 | 51 | 33 |
| 30 | 10 | 0 | 25 | 16 | 1 | 0 | 0 | 1 |
| 31 | 46 | 27 | 12 | 43 | 57 | 33 | 15 | 47 |
| 32 | 6 | 1 | 19 | 12 | 11 | 0 | 27 | 17 |
| 33 | 5 | 0 | 17 | 11 | 25 | 16 | 8 | 33 |
| 34 | | | | | | | | |
| 35 | 21 | 6 | 19 | 27 | 8 | 0 | 22 | 14 |

Since a misprint occurred in the typing of item thirty-four of Part II, Form A, this item has been omitted in both forms.

## INTERPRETATION OF ITEM ANALYSIS DATA

Davis states that items with discrimination indices above 20 will ordinarily be found to have sufficient discriminating power for use in most achievement tests.[31] Since it is generally accepted that an item should fail a minimum of 15% and a maximum of 85% of the sample, the difficulty index of items as shown in Tables IX and X should fall between 28 and 72.

Tables IX and X would indicate that six items of Form A and fourteen items of Form B have indices of discrimination lower than 20. These items lack sufficient discriminating power to be included in a test of achievement. However, four of the items of Form A and two of Form B have indices of 19 and so might be acceptable items. Two of the items of Form B, numbers one and thirty of Part II, have absolutely no power of discriminating high and low-scoring students.

Tables IX and X also show that the difficulty indices of six Form A items and seven Form B items fall below 28, three of these being above 25 in Form A and one in Form B. Four items of Form A and two of Form B, have indices greater than 72. Since easy items may be included as lead-on questions they can be used to advantage on the tests. However, the placement of these items must be at the beginning of Part I or Part II of either form. One item, number seven of Part I, Form A does not satisfy this condition. It should be item three of Part I, Form A.

The item-analysis of the Edmonton Test of Equivalence has revealed one very serious defect of the test. While the greater part of the items fall within the required range of difficulty, the items are not placed in increasing order of difficulty in Forms A or B. That it is essential to rearrange the items of the tests is strongly indicated by item analysis results.

THE EFFECT OF THE SPEED ELEMENT ON THE ITEM ANALYSIS DATA

In administering a speed test such as the Edmonton Test of Equivalence in Mathematics, there will necessarily be a group of students who, for lack of time, did not reach the items near the end of the test. Davis makes the assumption that these individuals, if granted additional time in which to finish, would have distributed their answers as did the individuals who did answer the items in the time limit. Davis feels this to be a practical assumption even though he feels that empirical validity checks would not bear out this conclusion. As a result of this assumption, he uses as the numerator for determining difficulty of an item:

$$N - NR \qquad (32)$$

where:

N = the number of testees in the sample,
NR = the number of testees in the sample that do not reach the item in the time limit.

If the test is speeded, succeeding items toward the end will have been read by a steadily decreasing number of subjects, resulting in the number of testees used to compute the proportion required to enter the

item analysis chart becoming steadily smaller. As a result, the reliability of the item analysis data for succeeding items decreases, sometimes to the point where the data are no longer worth computing. Davis feels that the progressive reduction in the number of cases on which the proportion required to enter the item analysis is calculated will not seriously bias the difficulty and discrimination indices if correction for chance formulas are used.

> There is, however, a factor that does operate especially to bias discrimination indices computed for items which a large proportion of the high-scoring and low-scoring groups have not reached in the time limit. It is the usual tendency of some testees in the low-scoring group to rush through the test, marking almost at random in an effort to try every item within the time limit. Members of the high-scoring group ordinarily do this to a far smaller extent, so the items near the end of a highly speeded test tend to have spuriously high discrimination indices.....33

As the Edmonton Test of Equivalence in Mathematics was not a highly speeded test, perhaps the results of the item analysis were not seriously affected. However, the correction for chance was used. It should be noted, that some of the low-scoring group computed each item and so did not complete the test. The formula for correction for chance, excluding this group, assumes that they would have performed as the higher group did. The items toward the end of the test therefore have spuriously low discrimination indices even when obtained by the correction for chance which Davis advocates.

# CHAPTER VII

## THE SUBTESTS OF THE EDMONTON TEST OF EQUIVALENCE IN MATHEMATICS

As was previously stated in Chapter IV, reliability measures for the total score of a test do not insure the reliability of the subtests. Each subtest is a test in itself and must demonstrate adequate reliability. By means of the product-moment coefficient of correlation, Forms A and B of the Computation, Denominate Number, Algebra and Geometry subtests were correlated. The data used to construct the scattergrams of the paired scores on the four subtests for Forms A and B of the Edmonton Test of Equivalence is found in Table 2 of Appendix C. Table XI shows the results of the calculations of the product-moment coefficients of correlation.

TABLE XI : PRODUCT-MOMENT COEFFICIENTS OF CORRELATION BETWEEN FORMS A AND B OF THE FOUR SUBTESTS OF THE EDMONTON TEST OF EQUIVALENCE IN MATHEMATICS

| | Computation | Denominate Number | Algebra | Geometry |
|---|---|---|---|---|
| Product-Moment Coefficients of Correlation Between Forms A and B | 0.71 | 0.64 | 0.82 | 0.77 |

While none of the scales indicates a high degree of reliability, the Algebra subtest would seem to be more reliable than the others and the Denominate Number the least reliable. Since few diagnostic achievement tests have published reliability coefficients for subtests,

the interpretation of these reliability measures is made difficult. The data of Table XII taken from Cronback provides a means of comparing results of the Edmonton Test of Equivalence subtest reliabilities with those of the Wechsler-Bellevue Adult Intelligence subtests.

TABLE XII: COEFFICIENTS OF EQUIVALENCE FOR SUBTESTS OF WECHSLER TEST, BASED ON 100 CASES WITH IQ 40 TO 100

| Subtest | Correlation between Forms I & II | s.d. (raw) | Presumable Reliability in unrestricted group | Probable Error of weighted score |
|---|---|---|---|---|
| Information | .73 | 2.2 | .86 | 1.1 |
| Vocabulary | .68 | 1.4 | --- | --- |
| Comprehension | .44 | 2.0 | .78 | 1.4 |
| Similarities | .55 | 2.2 | .70 | 1.6 |
| Digit Span | .63 | 2.4 | .78 | 1.4 |
| Arithmetic | .65 | 2.3 | .79 | 1.4 |
| Block Design | .80 | 2.7 | .85 | 1.2 |
| Digit Symbol | .81 | 2.1 | .92 | 0.8 |
| Picture Arrangement | .63 | 2.5 | .76 | 1.5 |
| Picture Completion | .34 | 2.5 | .54 | 2.0 |
| Object Assembly | .56 | 3.5 | .54 | 2.0 |

(Table taken from Cronback, The Essentials of Psychological Testing, 1949. p.151 )

The reliability of a subtest, however, indicates only that the test is consistent. To use subtests for diagnostic purposes, each subtest must possess some degree of uniqueness. To ascertain the relationship between the four subtests of the Edmonton Test of Equivalence in Mathematics, the scores of the four subtests were intercorrelated by the product-moment coefficient of correlation. The data for constructing the scattergrams of the paired scores on the forms for each subtest is found in Table 2 of Appendix C. Table XIII shows the intercorrelations between the subtests for Forms A and B.

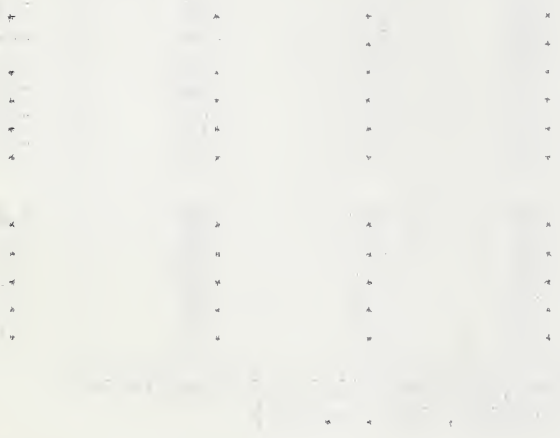

TABLE XIII : PRODUCT-MOMENT COEFFICIENTS OF CORRELATION BETWEEN THE SUBTESTS OF THE EDMONTON TEST OF EQUIVALENCE IN MATHEMATICS

| | Form A | | | Form B | | |
|---|---|---|---|---|---|---|
| | Comp. | Den. No. | Algebra | Comp. | Den. No. | Algebra |
| Computation | | | | | | |
| Denominate Number | 0.47 | | | 0.45 | | |
| Algebra | 0.68 | 0.39 | | 0.72 | 0.33 | |
| Geometry | 0.61 | 0.52 | 0.54 | 0.64 | 0.50 | 0.60 |

The results would indicate highest correlation between the computation subtest and the algebra and geometry scales. The correlations between the geometry scales and both the denominate number and algebra scales are also fairly high. It would seem, then, that there is fairly high correlation between the geometry scale and all three of the other subtests. The lowest correlations are those of the denominate number scale with the computation and algebra subtests.

While the reliabilities of the subtests would not indicate that they can be used to make predictions about individual students, they would appear to be reliable enough to use in evaluation and diagnosis of class performance. Since the intercorrelations of the subtests would also suggest that each scale, though testing some overlapping abilities, is contributing something new to the total score, the subtests should be useful to teachers in devising group remedial

work. The moderate intercorrelations of the subtests might also suggest that total scores might not be too meaningful. The reliability measures for Forms A and B might substantiate this claim, for internal consistency results were 0.86 and 0.87 respectively, while the total score reliability dropped to 0.84.

# CHAPTER VIII

## THE PRACTICE EFFECT OF TAKING THE ALTERNATE FORM OF THE EDMONTON TEST OF EQUIVALENCE IN MATHEMATICS

### MEASURING PRACTICE EFFECT

In administering the Edmonton Test of Equivalence to the students of the Edmonton Separate Schools, the total population of 300 Grade IX pupils was divided by classrooms into two groups. Group I, composed of 149 pupils, was given Form A in the morning and Form B in the afternoon, while the 151 pupils of Group II were given Form B in the morning and Form A in the afternoon.

Group I achieved a mean score of 34.20 on Form A and 36.55 on Form B. The mean difference of 2.35 was highly significant and could indicate that the mean of Form B was raised through practice effect or that Form B was an easier test than Form A. The mean for Group II on Form B was 27.40 and on Form A 31.35. Here, too, the mean difference of 3.95 was highly significant, the difference again being due either to practice effect or to the fact that Form A was an easier test than Form B. Since both groups scored significant mean gains on the second form of the test taken, it may be concluded that practice effect resulted in the gains of 2.35 and 3.95, and since the samples are roughly even may give an average practice effect of 3.15.

### THE GROUPING OF THE SAMPLE TO STUDY PRACTICE EFFECT

The purpose of dividing the Grade IX population into two groups had been to equalize practice effect on both forms so that results of reliability, validity and item analysis techniques would be comparable for both forms of the test. However, on examination of the two groups certain comparisons

emerged which merit study.

TABLE XIV : MEANS AND STANDARD DEVIATIONS FOR GROUPS I AND II ON THE GENERAL TEST AND GRADE IX MATHEMATICS FINAL

| | Mean | | Mean Diff. | Standard Dev. | | Mean Diff. |
|---|---|---|---|---|---|---|
| | Group I | Group II | | Group I | Group II | |
| Grade IX General Test | 110.60 | 110.65 | Not sig. | 12.40 | 10.10 | Sig. |
| Grade IX Math. Final (Raw Score) | 54.60 | 48.60 | Sig. | 18.90 | 18.10 | Not sig. |

The results of Table XIV would clearly indicate that though the two groups have the same average intelligence, Group I has greater variability of intelligence and at the same time is a better group of mathematics students than Group II.

In order to check whether this biased division of the groups would seriously contaminate results to a point which would render them invalid, Groups I and II were matched by pairing students according to their score on the Grade IX mathematics final. Pairing was done by allowing as great a difference as five points between the two scores. The groups were necessarily decreased in number, each of the new groups consisting of 120 students. The data of Table XV would indicate that the two were adequately matched in terms of mathematical ability.

TABLE XV : MEANS AND STANDARD DEVIATIONS OF THE MATCHED GROUPS ON THE GRADE IX MATHEMATICS FINAL

| | Group I | Group II |
|---|---|---|
| Mean | 52.10 | 51.80 |
| Standard Deviation | 18.90 | 18.40 |

The scores of the two matched groups were combined and the total distributions of scores on the two forms of the Edmonton Test of Equivalence determined. Table XVI shows the means and standard deviations of the distribution of scores on the Edmonton Test of Equivalence for the original and matched groups.

TABLE XVI : MEANS AND STANDARD DEVIATIONS OF ORIGINAL AND MATCHED GROUPS ON FORMS A AND B OF THE EDMONTON TEST OF EQUIVALENCE

| | Original Group | | Matched Group | |
|---|---|---|---|---|
| | Form A | Form B | Form A | Form B |
| Mean | 32.78 | 31.95 | 33.05 | 32.10 |
| Standard Deviation | 10.75 | 10.95 | 10.65 | 10.45 |

For both the original and matched groups, the distribution of scores for Form A was unimodal and for Form B bimodal. The test results of matching Groups I and II would seem to follow the trends of the original data, in which case it might appear that the division of the sample did not seriously contaminate the results.

# CHAPTER IX

## THE COMPARABILITY OF THE FORMS

Educators have stressed the need for comparable forms of tests as a means of measuring the effect of teaching. Rather than repeat the same test, it is desirable to use equivalent forms of the same test in order to rule out the effect of memory. Equivalent forms are also used to confirm or correct test scores which might possibly be inaccurate owing to emotional disturbance of the pupil or other unfavorable conditions.[34]

Two or more forms of an educational test are considered to be equal or equated when practically identical scores on each are made by the same individuals or by individuals of the same ability. This means that the forms of the test must be made up of test items which parallel one another closely in difficulty.[35]

In devising the Edmonton Test of Equivalence, the procedure used to achieve equivalence of forms was the construction of parallel items. The items in the two forms were designed to parallel each other as much as possible as to content and difficulty. "An exact equivalence of difficulty is not demanded of each pair of items, as a slight difference in difficulty for the two items of one pair may be compensated by an opposite and equivalent difference in difficulty for items of another pair." [36]

In comparing Forms A and B of the Edmonton Test of Equivalence in Mathematics, the following procedure was adopted.

1. The differences between the means and standard deviations of the distributions of the forms were tested for significance.

2. Comparisons of the item difficulty and discriminating power of the items of the two forms were made.

3. The bimodality of Form B was studied.

## COMPARISONS OF THE MEANS AND STANDARD DEVIATIONS

A common method of describing distributions uses the mean and standard deviation as the measures of comparison. The mean is the arithmetic average obtained by adding all scores and dividing by the number of scores. The standard deviation is a measure of the spread of scores.[37] The distributions of scores on Forms A and B of the Edmonton Test of Equivalence are shown in Table III of Chapter V. The mean and standard deviation for Form A were 32.78 and 10.75 and for Form B 31.95 and 10.95. The calculations of the reliability of the differences between the correlated means and standard deviations are shown in Table XVII.

TABLE XVII : RELIABILITY OF THE DIFFERENCES IN MEANS AND STANDARD DEVIATIONSOF 300 SCORES ON FORMS A AND B OF THE EDMONTON TEST OF EQUIVALENCE

| | Form A | Form B |
|---|---|---|
| No. of students | 300 | 300 |
| Mean score | 32.78 | 31.95 |
| Standard deviation | 10.75 | 10.95 |
| Correlation between Forms A and B | 0.84 | |

| Reliability of the difference between correlated means | | |
|---|---|---|
| | Form A | Form B |
| Standard error of the mean | 0.62 | 0.63 |
| Difference between means | 0.83 | |
| Standard error of the difference | 0.35 | |
| Critical ratio | 2.37 Significant | |

| Reliability of the difference between correlated sigmas | | |
|---|---|---|
| | Form A | Form B |
| Standard error of the standard deviation | 0.44 | 0.45 |
| Difference between standard deviations | 0.20 | |
| Standard error of the difference | 0.33 | |
| Critical ratio | 0.60 Not significant | |

The calculations show that the difference between the means is significant and so cannot be attributed to errors in sampling. Since

practice effect had been equalized by alternating the form which the group took first, the difference in mean score was probably due to some factor in the tests themselves. Form A is probably an easier test than Form B. The results of Table XIX, however, do not indicate that there is reason for believing a real difference in variability of test scores exists between the two forms.

## COMPARISON OF THE ITEMS OF THE TWO FORMS

To achieve close equality of item difficulty in the alternate forms of the Edmonton Test of Equivalence, the procedure followed was the preparation of parallel items. From Tables IX and X in Chapter VI, it is obvious that very few of the items are of parallel difficulty. However, when the items are arranged in increasing order of difficulty as shown in Table XVIII for both forms, the items are much more comparable.

TABLE XVIII : REARRANGEMENT OF ITEMS OF FORMS A AND B IN INCREASING ORDER OF DIFFICULTY ACCORDING TO DIFFICULTY LEVEL OBTAINED BY DAVIS ITEM ANALYSIS CHART

| ITEM | Difficulty Level of Form A | Difficulty Level of Form B | ITEM | Difficulty Level of Form A | Difficulty Level of Form B |
|---|---|---|---|---|---|
| 1 | 84 | 99 | 36 | 44 | 46 |
| 2 | 78 | 81 | 37 | 44 | 45 |
| 3 | 77 | 72 | 38 | 43 | 45 |
| 4 | 73 | 70 | 39 | 43 | 44 |
| 5 | 68 | 65 | 40 | 42 | 44 |
| 6 | 65 | 65 | 41 | 42 | 42 |
| 7 | 63 | 63 | 42 | 42 | 41 |
| 8 | 63 | 63 | 43 | 42 | 40 |
| 9 | 62 | 63 | 44 | 42 | 39 |
| 10 | 61 | 61 | 45 | 42 | 39 |
| 11 | 59 | 60 | 46 | 42 | 38 |
| 12 | 58 | 58 | 47 | 41 | 37 |
| 13 | 58 | 55 | 48 | 38 | 37 |
| 14 | 57 | 55 | 49 | 37 | 35 |
| 15 | 56 | 55 | 50 | 37 | 35 |
| 16 | 56 | 55 | 51 | 37 | 35 |
| 17 | 56 | 54 | 52 | 35 | 34 |
| 18 | 55 | 53 | 53 | 34 | 34 |
| 19 | 54 | 53 | 54 | 33 | 34 |
| 20 | 53 | 53 | 55 | 32 | 33 |
| 21 | 52 | 52 | 56 | 32 | 33 |
| 22 | 52 | 51 | 57 | 32 | 33 |
| 23 | 52 | 51 | 58 | 30 | 31 |
| 24 | 51 | 51 | 59 | 30 | 30 |
| 25 | 51 | 51 | 60 | 30 | 29 |
| 26 | 49 | 51 | 61 | 30 | 29 |
| 27 | 48 | 51 | 62 | 29 | 29 |
| 28 | 48 | 50 | 63 | 28 | 26 |
| 29 | 48 | 49 | 64 | 27 | 20 |
| 30 | 47 | 49 | 65 | 26 | 17 |
| 31 | 47 | 48 | 66 | 25 | 14 |
| 32 | 47 | 47 | 67 | 16 | 9 |
| 33 | 45 | 47 | 68 | 12 | 7 |
| 34 | 45 | 47 | 69 | 11 | 1 |
| 35 | 44 | 46 | | | |

The last six items of Form B would seem to be much more difficult than the paired items in Form A, while the first item in Form B is much simpler than the item in Form A. These items might result in making Form B a harder test than Form A.

From Tables IX and X in Chapter VI, it is also evident that if, as stated in Chapter VI, discrimination indices of 20 are desirable for items of achievement tests, Form A has six items whose indices fall below 20, their indices being 19, 19, 19, 19, 17 and 12, while Form B has fourteen items whose indices fall below 20, their indices being 19, 19, 17, 16, 16, 15, 14, 14, 14, 12, 11, 8, 0, and 0. The items of Form B would seem to be less valid than those of Form A and as a result less reliable. The validity coefficients of Table IV in Chapter V would bear out this finding concerning validity of Form B. The results of Chapter VI would not, on the other hand confirm that Form B is less reliable than Form A. That the two forms are not too highly consistent is substantiated by the product-moment coefficient of correlation found to be 0.84. However, the method of rational equivalence would indicate that Form B is more reliable than Form A. It must be stressed, of course, that the bimodal distribution of scores for Form B makes correlation results dubious.

While the items of Form B seem to be more difficult than those of Form A, neither form has a normal distribution of difficulty of items. The chi-square test of Table XIX indicates that the

distributions of item difficulty are significantly different from what would be a normal distribution of difficulty in items of a test in which items fail at most 85% of the sample and at least 15%.

TABLE XIX : CHI-SQUARE TEST FOR TESTING THE DIVERGENCE OF THE DISTRIBUTIONS OF ITEMS OF FORMS A AND B OF THE EDMONTON TEST OF EQUIVALENCE FROM THE DISTRIBUTION OF DIFFICULTY OF ITEMS ON THE HYPOTHESIS OF A NORMAL DISTRIBUTION

| Form A | | | | | | |
|---|---|---|---|---|---|---|
| Observed $f_o$ | 8 | 14 | 37 | 6 | 4 | 69 |
| Expected $f_e$ | 2 | 17 | 31 | 17 | 2 | 69 |
| $f_o - f_e =$ | 6 | 3 | 6 | 9 | 2 | |
| $(f_o - f_e)^2 =$ | 36 | 9 | 36 | 81 | 4 | |
| $\frac{(f_o - f_e)^2}{f_e} =$ | 18 | 0.53 | 1.1 | 4.76 | 2 | |
| $\chi^2 =$ | 26.39 | | | df = (5 - 1)(2 - 1) = 4 | | |

| Form B | | | | | | |
|---|---|---|---|---|---|---|
| Observed $f_o$ | 10 | 16 | 32 | 7 | 4 | 69 |
| Expected $f_e$ | 2 | 17 | 31 | 17 | 2 | 69 |
| $f - f_e =$ | 8 | 1 | 1 | 10 | 2 | |
| $(f_o - f_e)^2 =$ | 64 | 1 | 1 | 100 | 4 | |
| $\frac{(f_o - f_e)^2}{f_e} =$ | 32 | 0.06 | 0.32 | 0.17 | 2 | |
| $\chi^2 =$ | 34.55 | | | df = (5 - 1)(2 - 1) = 4 | | |

In both Forms A and B it would appear that the tests have too many hard items and an insufficient number of easy items. Testing the distribution of Form A for skewness, by use of the formula:

$$S_K = \frac{(P_{90}+P_{10})}{2} - P_{50} \qquad (38)$$

(a measure of skewness in terms of percentiles)

a result of 1.03 was obtained. This indicates that the distribution was positively skewed but when tested for significance, the standard error of the measure of skewness was 0.81 which yielded a critical ratio of 1.27 which is not highly significant. The lack of a sufficient number of easy items in Form A has not, therefore, resulted in extreme grouping of scores at one end of the scale. To discuss skewness of the distribution of Form B scores would be to conceal the bimodality of the results.

## THE BIMODALITY OF FORM B

The rarity in nature of the occurrence of bimodal distributions might well give rise to speculation concerning the cause of the bimodality of Form B scores. Since bimodality was not evident in Form A, defective items in Form B could cause deviation from normalcy. From the discussion of item analysis in Chapter VI, it is evident that Form B has more items that do not discriminate high and low-scoring

students than has Form A. This might tend to be a contributing factor to the bimodality of Form B.

The dividing of the Grade IX students into Groups I and II, where Group I had greater variability of intelligence and was a better group of mathematics students than Group II might also have caused the bimodality. Walker states that artificial bimodality can be achieved by such grouping.[39] However, when the two groups were matched for mathematical ability the same bimodality occurred suggesting that the grouping in itself was not the cause of the bimodality of scores on Form B.

The deviation from normalcy of the Form B results could also have been the result of failure on the part of some teachers to comply with the Directions For Administration which were issued with the test. Only by re-administration could this be checked.

In achievement tests, a serious cause of variation of test results may be attributed to the standards of instruction which exist in the schools. If a portion of the students had been very well trained while another portion were poorly trained, both forms of the test should have been equally affected, except as variation in items existed. Since the lack of equivalence is evident in the items of the two forms, bimodality of scores might have occurred if a group of the students had been thoroughly taught the relationships involved in certain items of Form B, while other groups had not.

"A statistical study can only describe what is; it cannot determine what ought to be except in so far as it may throw light upon the probable concomitants and consequences of certain situations."[40] This is particularly true in this problem of bimodality of scores. Only if extreme care were taken to control the variable factors could the cause of the bimodality of Form B be determined.

# CHAPTER X

## CONCLUSIONS

1. The reliability of the Edmonton Test of Equivalence in Mathematics as determined by the product-moment coefficient of correlation between Forms A and B of the test for 300 Grade IX students of the Edmonton Separate Schools was 0.84. The method of rational equivalence yielded a correlation of 0.86 for Form A and 0.87 for Form B. Since correlations higher than 0.90 are usually demanded of tests to be used for individual diagnosis, the tests are not sufficiently reliable for this purpose. However, tests analyzed from data obtained from a restricted, preselected group, as in this study, tend to have lower coefficients of reliability than if administered to a wider range of students. More conclusive measures of reliability would have been obtained if the tests had been administered to Grades VII to IX or IX to XI. The Edmonton Test then would have proven to be sufficiently reliable for individual prediction.

2. Three validity coefficients were obtained for each of the forms of the Edmonton Test of Equivalence.

a. Validity coefficients of 0.77 and 0.76 were obtained by correlating the scores of 300 Grade IX students on Form A and Form B of the Edmonton Test of Equivalence and the Departmental Grade IX mathematics final. While an r of less than 0.80 is generally considered low, validity coefficients of tests rarely rise above

0.70, though this gives far from perfect predictive accuracy. Since the restricted range of the group has also tended to lower the validity coefficients, the Edmonton Test of Equivalence would seem to be sufficiently valid to be used to measure achievement in Grade IX mathematics.

b. Forms A and B of the Edmonton Test of Equivalence correlated 0.73 and 0.67 with total score on the Grade IX finals. The validity of Form B is considerably lower than that of Form A. Although, coefficients of 0.70 give far from perfect predictive efficiency, in view of the restricted sample used to obtain these coefficients, Form A might be useful as an aid in measuring achievement in Grade IX finals. The validity of Form B might be improved by revising items which fail to discriminate high and low-scoring students.

c. Against the criterion of the Grade IX General Test, Forms A and B of the Edmonton Test of Equivalence yielded validity coefficients of 0.60 and 0.53. These coefficients would indicate that mathematical ability is positively but not highly related to intelligence in selected and homogeneous groups. Though the restricted range lowered the correlation measures, the results would indicate that I.Q.'s could not be used to measure achievement in Grade IX mathematics. Under or over-achievement in mathematics could not be assumed in relation to intelligence scores. Again it is to be noted that the validity of Form B is much lower than that of Form A. This would verify previous findings which indicated the need to revise Form B.

3. The reliability of the subtests of the Edmonton Test of Equivalence secured by correlating 300 Grade IX scores on Forms A and B were: Computation, 0.71; Denominate Number, 0.64; Algebra, 0.82; and Geometry, 0.77. Since moderately low intercorrelations were also found between the subtests of both forms, the scales would be sufficiently reliable and valid for the purpose of classroom guidance in mathematics.

4. Forms A and B of the Edmonton Test of Equivalence have too many very difficult items and an insufficient number of easy items. On Form A, items 7, 17, 30, 32, 33 and 35 of Part II are too difficult, while on Form B, items 17, 24 and 33 of Part I and 7, 30, 32 and 35 of Part II were too difficult.

5. The following items have low 'discriminating' power as shown by the Davis technique: Form A; Part I, 9; Part II, 5, 31, 32, 33 and 35: Form B; Part I, 1, 2, 10, 17, 19, 33, 34; Part II, 1, 3, 8, 26, 30, 31 and 33.

6. To maintain parallel-item construction in Forms A and B, item 10 of Part I and items 7, 30, 31, 32, 33 and 35 should be eliminated from both forms, for they are defective items in both tests. All other items failing to meet the requirements of difficulty and (or) discrimination need to be revised to make them parallel to the corresponding item in the alternate form.

7. The items of the Edmonton Test of Equivalence were not arranged in increasing order of difficulty. To maintain the parallelism of the two forms, the order of the items of the two forms would be: Part I, 1, 2, 7, 5, 8, 11, 3, 9, 4, 19, 14, 17, (10), 16, 34, 13, 6, 28, 23, 20, 15, 22, 31, 12, 25, 35, 18, 27, 30, 21, 32, 26, 24, 33 and 29; Part II, 1, 8, 2, 5, 3, 4, 12, 6, 13, 11, 18, 21, 24, 22, 9, (31), 10, 16, 19, 25, 26, 28, 14, 20, 27, 29, 23, 15, (35), (7), 17, (30), (32) and (33).

8. The results of the analysis of the Edmonton Test of Equivalence in Mathematics would clearly indicate that the strength of a test depends on its items, for both reliability and validity are affected if the items are not first refined by item analysis.

9. The practice effect of taking the second form of the Edmonton Test of Equivalence is a gain in total score of 3.15 scale units.

10. Item analysis can detect defective items by establishing discriminating power and difficulty level of items, however, such procedures need not necessarily identify items faulty in mathematical content. Since the writer devised the Edmonton Test of Equivalence, no analysis of the mathematical content of the test has been made in this study. It would be advisable to have such an analysis carried out before the test were revised.

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# APPENDIX A

Copies of Forms A and B of the Edmonton Test of Equivalence in Mathematics and Directions for Administration of the Test.

# DIRECTIONS FOR THE ADMINISTRATION OF THE TEST

1. Time of administration

   a. This is a test of equivalence in Mathematics at the Grade IX level. It consists of 2 forms, FORM A and FORM B. Each form is made up of 2 separately timed sections, Part I (20 minutes) and Part II (25 minutes).

   b. At 9:15 o'clock on Wednesday, June 18, FORM  of the test is to be administered to all Grade IX students of the school. The first two periods of the day are to be set aside for this purpose.

   c. At 1:45 on Wednesday, June 18, FORM  of the test is to be administered to all Grade IX students of the school. The first two periods of the afternoon are to be set aside for this purpose.

   (STUDENTS ARE NOT TO BE TOLD OF THIS SECOND TEST)

2. Directions to students prior to testing

   a. On Tuesday, June 17, the Grade IX students are to be told that there will be a test in Mathematics on Wednesday morning. No further information about the test should be given other than that it will cover their course in Mathematics.

   b. The students are NOT to be told that a second form of the test is to be given on Wednesday afternoon.

3. General directions to the examiner.

   a. The examiner should see that each student has a pencil and eraser. All work is to be done on the test paper so no scratch paper is required.

   b. Since a testing situation is desired, the correct responses, except in practice exercises and as instructed, should in no way be indicated. No questions are to be answered after the test has started. In the event of any error(s) in the test, nothing should be done to correct the item(s) during the test period. A report should be made of the error(s) when the test papers are returned to the Separate School Board Office.

4. Directions to the examiner for the giving of the tests

(THESE DIRECTIONS ARE TO BE USED FOR BOTH FORM A AND FORM B)

a. Distribute the test papers to the pupils, placing them on the desk with the title page up. The students are to be told NOT TO TURN THE FRONT PAGE.

b. Have the pupils fill in the data required on the front page. (READ WHAT IS REQUIRED DIRECTLY FROM A TEST PAPER)

c. Call the attention of the students to the Directions of Part I, asking them to read them silently as the directions are read aloud. (READ THE DIRECTIONS TO PART I DIRECTLY FROM A TEST PAPER TO THE END OF THE SECOND EXAMPLE.)

d. After the second example, stop. Answer any questions that the students may ask. If asked about guessing, advise pupils that they will not be penalized for so doing.

e. Then read the rest of the directions. Read with emphasis the time allowance and the final warning. Then say, "READY, BEGIN."

f. Allow 20 minutes to pass and then say, "STOP WORK. LOOK AT THE DIRECTIONS FOR PART II."

g. Read the directions for Part II aloud while the pupils follow the directions silently. (READ DIRECTLY FROM A TEST PAPER TO THE END OF THE SECOND EXAMPLE)

h. After example 2, answer any questions that the pupils may ask.

i. Then read the rest of the directions. Read with emphasis the time allowance and the final warning. Then say, "READY, BEGIN."

j. Allow 25 minutes to pass and then say, "STOP WORK. TURN THE TEST PAGES OVER PLACING THE TITLE PAGE UP."

k. Collect the test booklets. If any of the pages become separated from the other pages of the test see that the pupil's name is placed on each sheet of the test.

A TEST TO MEASURE KNOWLEDGE OF EQUIVALENCE IN MATHEMATICS AT THE GRADE IX LEVEL

F-O-R-M A

Name_____

Date of Birth_____
Month Date Year

Age_____ Grade_____ Boy_____ Girl_____

School_____ City_____

Teacher_____ Date_____

| | SCORES | | |
|---|---|---|---|
| | Part I | Part II | Total |
| 1. a | | | |
| b | | | |
| 2. | | | |
| 3. | | | |
| Total | | | |

Directions - Part I

Each of the questions in this section consists of 4 items placed in a row. One item in each row is NOT equivalent to the other three in the row.

Below is an example already answered correctly. Notice how the question is answered.

| | A | B | C | D | | | | |
|---|---|---|---|---|---|---|---|---|
| 1. | $7+6$ | $(9+5)$ | $10+3$ | $8+5$ | $\overline{A}$ | $\overline{\overline{X}}$ | $\overline{C}$ | $\overline{D}$ |

The item which is NOT equivalent to the other three is $9+5$ so $9+5$ is circled, and $\overline{\overline{9+5}}$ is part B, so an X has been put in the B answer space. This is the way you are to answer the questions.

Try this example yourself.

| A | B | C | D | | | | |
|---|---|---|---|---|---|---|---|
| $\frac{1}{2}$ | $\frac{4}{8}$ | $\frac{2}{7}$ | $\frac{10}{20}$ | $\overline{A}$ | $\overline{B}$ | $\overline{C}$ | $\overline{D}$ |

The item not equivalent to the other three is $\frac{2}{7}$ so you should have drawn a circle around $\frac{2}{7}$ and put an X in the C answer space.

In taking this test, answer the questions in the order in which they are given. Do not linger too long over difficult questions. It should not be necessary to work out every item of each question to find the part which is not the same as the other three. Do as little calculating as possible. If you change your mind about an answer, erase your first mark thoroughly.

YOU WILL HAVE EXACTLY 20 MINUTES TO DO PART I

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO BEGIN

| | A | B | C | D | |
|---|---|---|---|---|---|
| 1. | $9 + 6$ | $24 - 9$ | $21 - 7$ | $8 + 7$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 2. | $(1700 + 300)$ | $(500 + 1500)$ | $(12000 + 800)$ | $(100 + 1900)$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 3. | $7x - x$ | $7$ | $4x + 2x$ | $5x + x$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 4. | $\frac{10}{15}$ | $\frac{12}{18}$ | $\frac{2}{3}$ | $\frac{4}{9}$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 5. | $\frac{107}{13}$ | $\frac{180}{20}$ | $\frac{54}{6}$ | $\frac{36}{4}$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 6. | $\frac{21m^2}{7m}$ | $\frac{6m}{2m}$ | $\frac{3m^2}{m}$ | $\frac{12m^4}{4m^3}$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 7. | $(7)(8)$ | $(14)(4)$ | $(28)(2)$ | $(16)(3)$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 8. | $2(x)(x)$ | $4x$ | $2x^2$ | $(2x)(x)$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 9. | $18 - \frac{1}{4}$ | $24 - 6\frac{1}{4}$ | $15 + 2\frac{3}{4}$ | $20 - 1\frac{3}{4}$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 10. | $25.0 - 3.3$ | $18.6 + 2.7$ | $19.4 + 1.9$ | $24.2 - 2.9$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 11. | $\frac{9}{6}$ | $1.50$ | $1\frac{1}{3}$ | $1\frac{1}{2}$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 12. | $6x + 2$ | $8x$ | $\frac{18x + 6}{3}$ | $\frac{6(3x + 1)}{3}$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 13. | $3(2x - 1)$ | $6x - 1$ | $\frac{12x - 6}{2}$ | $5x - 3 + x$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 14. | $(892.1)(10)$ | $(8921)(1)$ | $(0.8921)(1000)$ | $(89.21)(100)$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 15. | $3x(12x + 6)$ | $6(6x^2 + 3)$ | $9(4x^2 + 2x)$ | $18x(2x + 1)$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |

GO ON TO NEXT PAGE

| | | | | | |
|---|---|---|---|---|---|
| 16. | $\frac{1}{8}$ | $12\frac{1}{2}\%$ | 0.125 | $\frac{125}{10,000}$ | A B C D |
| 17. | $\frac{7}{8}$ | 0.875 | $87\frac{1}{2}\%$ | 8.75 | A B C D |
| 18. | 0.130 | 130% | $\frac{13}{10}$ | 1.30 | A B C D |
| 19. | 2% of 40 | 4% of 20 | 8% of 5 | 1% of 80 | A B C D |
| 20. | A discount of $32 | A discount of $3.20 | A discount of 4% on $80 | A discount of 1/25 of $80 | A B C D |
| 21. | 1 | $\frac{10k - k}{10}$ | $\frac{7k}{7k}$ | $\frac{2k - k}{k}$ | A B C D |
| 22. | $\frac{\frac{1}{6}}{\frac{2}{3}}$ | $\frac{3}{12}$ | $\frac{\frac{1}{3}}{12}$ | $\frac{1}{4}$ | A B C D |
| 23. | $\frac{3 \div 5}{4 \div 5}$ | $\frac{(3)(6)}{(4)(6)}$ | $\frac{3}{4}$ | $\frac{3 + 2}{4 + 2}$ | A B C D |
| 24. | $9t - 9t$ | $\frac{4t}{4t}$ | 0 | $\frac{6t - 6t}{3}$ | A B C D |
| 25. | $\frac{9}{10}$ | 10% of 90 | 9.0 | 5% of 180 | A B C D |
| 26. | $(-8y)-(-16y)$ | $(+24y)\div(-3)$ | $(-12y)+(+20y)$ | $(-8)(-y)$ | A B C D |
| 27. | 1% of 81.6 | $(81.6)(\frac{1}{10})$ | (81.6)(0.1) | (0.816)(10) | A B C D |
| 28. | 8 | $4^2$ | $\sqrt{64}$ | $2^3$ | A B C D |
| 29. | $\frac{2}{5}\%$ | 0.004 | 40% | 0.4% | A B C D |
| 30. | $(+18k^2)-(38k^2)$ | $(-5k)(-4k)$ | $(-40k^2)\div 2$ | $(-17k^2)+(-3k^2)$ | A B C D |

GO ON TO NEXT PAGE

31. $(4x+2)(3x+6)$ $6(x+1)(x+2)$ $2(2x+1)(3x+6)$ $3(4x+2)(x+2)$ A B C D

32. A tax rate of $35 on $100 | A tax rate of 35 mills | A tax rate of $3\frac{1}{2}\%$ | A tax rate of 35¢ on $10 — A B C D

33. $d = \frac{C}{\pi}$ $\pi = \frac{d}{C}$ $C = 2\pi r$ $C = \pi d$ A B C D

34. $(17.62)(3.4)$ $(1762)(0.034)$ $(1.762)(34)$ $(0.1762)(3400)$ A B C D

35. $\frac{1526}{1.8}$ $\frac{15260}{18}$ $\frac{1.526}{0.18}$ $\frac{15.26}{0.018}$ A B C D

END OF PART I

IF YOU FINISH BEFORE YOU ARE TOLD TO STOP GO BACK TO SEE THAT YOUR WORK IS CORRECT.

DO NOT TURN THIS PAGE

Directions - Part II

In this section 2 statements are placed in a row. The statement on the right has to be completed in order that it be equivalent to the statement on the left. The following is a sample question already answered correctly. Notice how the question is answered.

| | | Answer |
|---|---|---|
| 1. A ruler is 1 ft. long. | 1. A ruler is 12 inches long. | 1. 12 |

Since 12 inches is equivalent to 1 foot, 12 is written in the statement and re-written in the answer space. This is the way you are to answer the questions. Try this example yourself.

| | | |
|---|---|---|
| 2. A team lost 6 out of 12 games played. | 2. A team lost 10 out of ___ games played. | 2. ____ |

The answer, of course, is 20, so you should have written 20 in the statement and re-written 20 in the answer space.

Answer the questions in the order in which they are given, but do not linger too long over difficult questions.

YOU WILL HAVE EXACTLY 25 MINUTES TO DO PART II

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO BEGIN

| | | |
|---|---|---|
| 1. A line 6 in. in length. | 1. A line ___ ft. in length. | 1.____ |
| 2. A distance of a mile. | 2. A distance of ___ feet. | 2.____ |
| 3. A weight of $1\frac{1}{2}$ tons of coal. | 3. A weight of ___ lb. of coal. | 3.____ |
| 4. 18 oz. of candy. | 4. ___ lb. of candy. | 4.____ |
| 5. 1% of 79.6. | 5. ___% of 7.96. | 5.____ |
| 6. John has 12k dollars. | 6. John has ___cents. | 6.____ |
| 7. The cost of 16 oranges at 30¢ a doz. | 7. The cost of 8 oranges at ___¢ a doz. | 7.____ |
| 8. A car travels 16 feet a second. | 8. A car travels ___ ft. a minute. | 8.____ |
| 9. The distance travelled in one minute by a 10 in. wheel making 8 revolutions a min. | 9. The distance travelled in one minute by a 5 in. wheel making ___ revolutions a min. | 9.____ |
| 10. The perimeter of a rectangle 4 ft. by 18 ft. | 10. The perimeter of a rectangle 5 ft. by ___ ft. | 10.____ |
| 11. The perimeter of a square of 5 in. | 11. The perimeter of a rectangle 8 in. by ___ in. | 11.____ |
| 12. The perimeter of a triangle of sides 4 ft., 7 ft. and 13 ft. | 12. The perimeter of an equilateral triangle of side ___ ft. | 12.____ |
| 13. The perimeter of an equilateral triangle of side 8 ft. | 13. The perimeter of an isosceles triangle of base 6 ft. and side ___ ft. | 13.____ |

GO ON TO NEXT PAGE

| | | |
|---|---|---|
| 14. Peter has (14-3j) cents. | 14. Peter has ___ nickels. | 14._____ |
| 15. $2x - 20 = 5x + 30$ | 15. $2x =$ | 15._____ |
| 16. 5% interest on $120 for 2 years. | 16. 2½% interest on $240 for ___ years. | 16._____ |
| 17. A loss of 8 games out of 40 played. | 17. A winning of 12 games out of ___ played. | 17._____ |
| 18. An area of one sq. yd. | 18. An area of ___ sq. ft. | 18._____ |
| 19. A square mile of land. | 19. ___ acres of land. | 19._____ |
| 20. The area of a rectangle 12 in by 3 in. | 20. The area of a square of side ___ in. | |
| 21. The area of a parallelogram of base 10 ft. and altitude 7 ft. | 21. The area of a parallelogram of base 5 ft. and altitude ___ ft. | 21._____ |
| 22. The area of a parallelogram of base 8 in. and height 5 in. | 22. The area of a triangle of base 8 in and height ___ in. | 22._____ |
| 23. A cubic foot of water. | 23. ___ cubic inches of water. | 23._____ |
| 24. The volume of a box 4 ft. by 6 ft. by 8 ft. | 24. The volume of a box 4 ft. by 3 ft. by ___ ft. | 24._____ |
| 25. The volume of a rectangular solid 2 in. by 4 in. by 8 in. | 25. The volume of a cube of side ___ inches. | 25._____ |

GO ON TO NEXT PAGE

| | | |
|---|---|---|
| 26. $3y + 7 = 2y - 4$ | 26. $9y + 21 =$ ___ | 26._____ |
| 27. The volume of a cone of radius 6 in. and height 9 in. | 27. The volume of a cylinder of radious 6 in. and height ___ in. | 27._____ |
| 28. A piece of cloth of 4 sq. in. | 28. A piece of cloth ___ inches sq. | 28._____ |
| 29. $\frac{x}{2} + 25 = \frac{x}{3} + 75$ | 29. $3x + 150 =$ ___ | 29._____ |
| 30. $2t + 35 = x + 30$ | 30. $4t + 50 =$ ___ | 30._____ |
| 31. The investment yielding at 3% yearly interest of $24. | 31. The investment yielding at 4% interest of $___ | 31._____ |
| 32. The volume of a cone of radius 10 in. and height 6 in. | 32. The volume of a cone of radius 5 in. and height ___ in. | 32._____ |
| 33. The original cost of a table selling for $60 at a "20% off sale". | 33. The original cost of a table selling for $50 at a "___% off sale ". | 33._____ |
| 34. The total area of 24 circles each of radius 7 in. | 34. The total area of 6 circles each of radius ___ in. | 34._____ |
| 35. The volume of a cone of radius 12 in. and height 6 in. | 35. The volume of a cylinder of radius 4 in. and height ___ in. | 35._____ |

END OF PART II

IF YOU FINISH BEFORE YOU ARE TOLD TO STOP GO BACK TO THE BEGINNING OF PART II TO SEE THAT YOUR WORK IS CORRECT.

DO NOT TURN BACK TO PART I

# A TEST TO MEASURE KNOWLEDGE OF EQUIVALENCE IN MATHEMATICS AT THE GRADE IX LEVEL

## F O R M  B

Name .....

Date of birth ..... Month Day Year

Age .....Grade ..... Boy.....Girl...

School .....City.....

Teacher .....Date.....

| | Score | | |
|---|---|---|---|
| | Part I | Part II | Total |
| La | | | |
| b | | | |
| 2 | | | |
| 3 | | | |
| T | | | |

Directions - Part I

Each of the questions in this section consists of 4 items placed in a row. One item in each row is NOT equivalent to the other three in the row.

Below is an example already answered correctly. Notice how the question is answered.

| | A | B | C | D | | | | |
|---|---|---|---|---|---|---|---|---|
| 1. | 7+6 | (9+5) | 10+3 | 8+5 | $\overline{A}$ | $\overline{\overline{X}}$ B | $\overline{C}$ | $\overline{D}$ |

The item which is NOT equivalent to the other three is 9 + 5, so 9 + 5 is circled, and 9+5 is part B, so an X has been put in the B answer space. This is the way you are to answer the questions.

Try this example yourself.

| | A | B | C | D | | | | |
|---|---|---|---|---|---|---|---|---|
| 2. | $\frac{1}{2}$ | $\frac{4}{8}$ | $\frac{2}{7}$ | $\frac{10}{20}$ | $\overline{A}$ | $\overline{B}$ | $\overline{C}$ | $\overline{D}$ |

The item not equivalent to the other three is $\frac{2}{7}$, so you should have drawn a circle around $\frac{2}{7}$, and put an X in the C answer space.

In taking this test, answer the questions in the order in which they are given. Do not linger too long over difficult questions. It should not be necessary to work out every item of each question to find the part which is not the same as the other three. Do as little calculating as possible. If you change your mind about an answer, erase your first mark thoroughly.

YOU WILL HAVE EXACTLY 20 MINUTES TO DO PART I.

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO BEGIN.

| | A | B | C | D | |
|---|---|---|---|---|---|
| 1. | $8 + 5$ | $31 - 16$ | $22 - 9$ | $9 + 4$ | A B C D |
| 2. | $(1,200+1200)$ | $(600+1,800)$ | $(20,000+400)$ | $(100+2,300)$ | A B C D |
| 3. | $3x+2x$ | $4x+x$ | $6x - x$ | $6$ | A B C D |
| 4. | $\frac{6}{10}$ | $\frac{2}{5}$ | $\frac{4}{10}$ | $\frac{10}{25}$ | A B C D |
| 5. | $\frac{42}{7}$ | $\frac{24}{3}$ | $\frac{48}{8}$ | $\frac{30}{5}$ | A B C D |
| 6. | $\frac{12z^2}{2z}$ | $\frac{12z}{2}$ | $\frac{60z^3}{10z^2}$ | $\frac{36z^4}{6z^2}$ | A B C D |
| 7. | $(16)(4)$ | $(18)(3)$ | $(9)(6)$ | $(27)(2)$ | A B C D |
| 8. | $(x^2)(2x)$ | $2(x)(x)(x)$ | $2x^3$ | $6x$ | A B C D |
| 9. | $13+2\frac{2}{3}$ | $16 - \frac{2}{3}$ | $17 - 1\frac{1}{3}$ | $14\frac{1}{3}+1\frac{1}{3}$ | A B C D |
| 10. | $16.1+19.9$ | $40.3 - 3.3$ | $32.3+4.7$ | $28.7+8.3$ | A B C D |
| 11. | $1\frac{1}{2}$ | $\frac{12}{8}$ | $1.125$ | $\frac{6}{4}$ | A B C D |
| 12. | $\frac{8x+8}{4}$ | $\frac{4(x+1)}{2}$ | $2x+2$ | $4x$ | A B C D |
| 13. | $\frac{24y - 8y^2}{2}$ | $(10y - 4y^2+ 2y)$ | $4y(3 - y)$ | $(12y - y)$ | A B C D |
| 14. | $(76.5)(10)$ | $(7.65)(100)$ | $(0.0765)(1000)$ | $(765.0)(1)$ | A B C D |
| 15. | $5m^2(6m+4)$ | $2m(15m^2+ 10m)$ | $10(3m^3+ 2m^2)$ | $m(30m^2+ 20)$ | A B C D |

GO ON TO NEXT PAGE

| | A | B | C | D | |
|---|---|---|---|---|---|
| 16. | $0.0\overline{4}$ | $40\%$ | $\frac{2}{5}$ | $0.40$ | A B C D |
| 17. | $87.5$ | $\frac{7}{8}$ | $0.8\frac{3}{4}$ | $87\frac{1}{2}\%$ | A B C D |
| 18. | $0.250$ | $2\frac{1}{2}$ | $250\%$ | $\frac{250}{100}$ | A B C D |
| 19. | 4% of 50 | 1% of 20 | 8% of 25 | 20% of 10 | A B C D |
| 20. | A discount of 5% on \$70 | A discount of \$3.50 | A discount of \$35 | A discount of $\frac{1}{20}$ of \$70 | A B C D |
| 21. | $1$ | $\frac{5s}{5s}$ | $\frac{2s - s}{s}$ | $\frac{8s - s}{8}$ | A B C D |
| 22. | $\frac{\frac{3}{8}}{\frac{1}{4}}$ | $\frac{3}{32}$ | $1\frac{1}{2}$ | $\frac{\frac{4}{8}}{3}$ | A B C D |
| 23. | $\frac{9 - 1}{11 - 1}$ | $\frac{9}{11}$ | $\frac{9 \div 3}{11 \div 3}$ | $\frac{(9)(2)}{(11)(2)}$ | A B C D |
| 24. | $\frac{2m - 2m}{7}$ | $3m - 3m$ | $0$ | $\frac{5m}{5m}$ | A B C D |
| 25. | 20% of 35 | $\frac{7}{10}$ | $7.0$ | 10% of 70 | A B C D |
| 26. | $(30z)-(10z)$ | $(-19z)+(+39z)$ | $(-20)(-z)$ | $(60z)\div(-3)$ | A B C D |
| 27. | $(978)(\frac{1}{100})$ | 100% of 0.978 | 10% of 9.78 | $(97.8)(0.01)$ | A B C D |
| 28. | $4^2$ | $\sqrt{256}$ | $2^4$ | $8$ | A B C D |
| 29. | $0.006$ | $\frac{3}{5}\%$ | $60\%$ | $0.6\%$ | A B C D |
| 30. | $(-12t^3)+(-3t^3)$ | $(+30t^3)-(+45t^3)$ | $(-30t^3)\div(2)$ | $(-3t^2)(-5t)$ | A B C D |

GO ON TO NEXT PAGE

| | A | B | C | D | |
|---|---|---|---|---|---|
| 31. | $2(6x+4)(2x+6)$ | $2(3x+2)(4x+12)$ | $8(3x+2)(x+3)$ | $4(2x+2)(x+3)$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 32. | A tax rate of $4\frac{1}{2}\%$ on \$1 | A tax rate of $4\frac{1}{2}\%$ | A tax rate of \$4½ on \$1000 | A tax rate of 45 mills | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 33. | $t=\frac{d}{r}$ | $d=rt$ | $t=\frac{1}{r}d$ | $r=\frac{t}{d}$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 34. | $(13.10)(1.96)$ | $(131.0)(0.196)$ | $(0.131)(19.6)$ | $(1310)(0.0196)$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |
| 35. | $\frac{0.01598}{0.2}$ | $\frac{15.98}{0.002}$ | $\frac{159.8}{0.02}$ | $\frac{1.598}{0.0002}$ | $\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ |

END OF PART I

IF YOU FINISH BEFORE YOU ARE TOLD TO STOP GO BACK TO SEE THAT YOUR WORK IS CORRECT

DO NOT TURN THIS PAGE

Directions for Part II

In this section 2 statements are placed in a row. The statement on the right has to be completed in order that it be equivalent to the statement on the left. The following is a sample question already answered correctly. Notice how the question is answered.

| | | | Answer |
|---|---|---|---|
| 1. | A ruler is 1 ft. long. | 1. A ruler is 12 inches long. | 1. 12 |

Since 12 inches is equivalent to 1 foot, 12 is written in the statement and re-written in the answer space. This is the way you are to answer the questions.

Try this example yourself.

| | | | |
|---|---|---|---|
| 2. | A team lost 6 out of 12 games played. | 2. A team lost 10 out of _____ games played | 2. _____ |

The answer, of course, is 20, so you should have written 20 in the statement and re-written 20 in the answer space.

Answer the questions in the order in which they are given, but do not linger too long over difficult questions.

YOU WILL HAVE EXACTLY 25 MINUTES TO DO PART II.

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO BEGIN.

| | | | | | |
|---|---|---|---|---|---|
| 1. | Half a foot of string. | 1. | _____ inches of string. | 1. | _____ |
| 2. | A distance of a mile. | 2. | A distance of _____ yds. | 2. | _____ |
| 3. | A weight of $2\frac{1}{2}$ tons of coal. | 3. | A weight of _____ lbs. of coal. | 3. | _____ |
| 4. | 20 oz. of nutmeg. | 4. | _____ lbs. of nutmeg. | 4. | _____ |
| 5. | $\frac{1}{10}$ of 89.6 | 5. | _____ % of 8.96 | 5. | _____ |
| 6. | Alec has 20¢ dimes. | 6. | Alec has _____ cents. | 6. | _____ |
| 7. | The cost of 18 oranges at 50¢ a dozen. | 7. | The cost of 10 oranges at _____ cents a dozen. | 7. | _____ |
| 8. | A plane travels 90 miles an hour. | 8. | A plane travels _____ miles a minute. | 8. | _____ |
| 9. | The distance travelled in one minute by an 18 in. wheel making 10 revolutions a minute. | 9. | The distance travelled in one minute by a 36 in. wheel making _____ revolutions a minute. | 9. | _____ |
| 10. | The perimeter of a rectangle 6 in. by 7 in. | 10. | The perimeter of a rectangle 5 in. by _____ in. | 10. | _____ |
| 11. | The perimeter of a square of 6 in. | 11. | The perimeter of a rectangle 3 in. by _____ in. | 11. | _____ |
| 12. | The perimeter of a triangle of sides 6 ft., 8 ft. and 7 ft. | 12. | The perimeter of an equilateral triangle of sides _____ ft. | 12. | _____ |
| 13. | The perimeter of an equilateral triangle of side 12. in. | 13. | The perimeter of an isosceles triangle of base 8 in. and side _____ in. | 13. | _____ |

GO ON TO NEXT PAGE

| | | |
|---|---|---|
| 14. Mary has $(17 - 3f)$ cents. | 14. Mary has _____ nickels. | 14. _____ |
| 15. $4y + 20 = 7y + 10$ | 15. $4y =$ | 15. _____ |
| 16. $3\frac{1}{2}\%$ interest on \$250 for 8 years. | 16. 7% interest on \$500 for _____ years. | 16. _____ |
| 17. Jean makes 4 errors in a spelling test of 32 words. | 17. Mary spells correctly 21 words in a test of _____ words. | 17. _____ |
| 18. An area of one sq.ft. | 18. An area of _____ sq.in. | 18. _____ |
| 19. A square mile of land. | 19. _____ acres of land. | 19. _____ |
| 20. The area of a rectangle 20 ft. by 5 ft. | 20. The area of a square of side _____ ft. | 20. _____ |
| 21. The area of a parallelogram of base 8 in. and altitude 12 in. | 21. The area of a parallelogram of base 16 in. and altitude _____ in. | 21. _____ |
| 22. The area of a parallelogram of base 12 ft. and altitude 5 ft. | 22. The area of a triangle of base 12 ft. and height _____ ft. | 22. _____ |
| 23. A cubic yard of sand. | 23. _____ cubic feet of sand. | 23. _____ |
| 24. The volume of a box 4 in. by 4 in. by 10 in. | 24. The volume of a box 2 in. by 2 in. by _____ in. | 24. _____ |
| 25. The volume of a rectangular solid 1 in. by 2 in. by 4 in. | 25. The volume of a cube of side _____ in. | 25. _____ |

GO ON TO NEXT PAGE

| | | |
|---|---|---|
| 26. $2t - 9 = 7t + 2$ | 26. $4t - 18 =$ _____ | 26. _____ |
| 27. The volume of a cone of radius 12 in. and height 6 in. | 27. The volume of a cylinder of radius 12 in. and height _____ in. | 27. _____ |
| 28. A piece of linoleum 9 inches square. | 28. _____ sq. in. of linoleum. | 28. _____ |
| 29. $\frac{x}{4} + 10 = \frac{x}{3} + 50$ | 29. $3x + 120 =$ _____ | 29. _____ |
| 30. $3h + 20 = 2h + 50$ | 30. $6h + 30 =$ _____ | 30. _____ |
| 31. The sum invested at 6% yielding yearly interest of $30 | 31. The sum invested at 10% yielding yearly interest of $ _____ | 31. _____ |
| 32. The volume of a cone of radius 12 in. and height 8 in. | 32. The volume of a cone of radius 24 in. and height _____ in. | 32. _____ |
| 33. The list price of a dress marked down to $15 at a "25%-off sale." | 33. The list price of a dress marked down to $_____ at a "20%-off sale." | 33. _____ |
| 34. The total area of 2 circles each of radius 6 inches. | 34. The volume of 18 circles each of radius _____ in. | 34. _____ |
| 35. The volume of a cone of radius 6 inches and height 12 in. | 35. The volume of a cylinder of radius 12 inches and height _____ in. | 35. _____ |

END OF PART II

IF YOU FINISH BEFORE YOU ARE TOLD TO STOP GO BACK TO THE BEGINNING OF PART II TO SEE THAT YOUR WORK IS CORRECT

DO NOT TURN BACK TO PART I

# APPENDIX B

Figure 1. Scattergram and Calculation of the Product-Moment Coefficient of Correlation Between Forms A and B of the Edmonton Test of Equivalence in Mathematics for 300 Grade IX Students.

Raw Scores on Form A ( X- Variable )

| Raw Scores on Form B ( Y- Variable ) | 5-10 | 10-15 | 15-20 | 20-25 | 25-30 | 30-35 | 35-40 | 40-45 | 45-50 | 50-55 | 55-60 | 60-65 | fy | $y^1$ | $fy^1$ | $fy^{1^2}$ | x | $y^1$ | $x^1$ | $x^1y^1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 60-65 | | | | | | | | | | 1 | | 2 | 3 | 7 | 21 | 147 | 112 | | 16 | 112 |
| 55-60 | | | | | | | | | | 1 | 2 | | 3 | 6 | 18 | 108 | 84 | | 14 | 84 |
| 50-55 | | | | | | | | | 1 | 4 | 2 | | 7 | 5 | 35 | 175 | 145 | | 29 | 145 |
| 45-50 | | | | | | 1 | 3 | | 5 | 10 | | | 19 | 4 | 76 | 304 | 232 | | 58 | 232 |
| 40-45 | | | | | 1 | 16 | 20 | 20 | 6 | 3 | | | 56 | 3 | 168 | 504 | 270 | -3 | 89 | 267 |
| 35-40 | | | | 1 | 2 | 9 | 12 | 7 | 2 | | | | 33 | 2 | 66 | 132 | 64 | -8 | 28 | 56 |
| 30-35 | | | | 3 | 5 | 7 | 11 | 3 | 1 | | | | 30 | 1 | 30 | 30 | 30 | -11 | 8 | 9 |
| 25-30 | | 1 | 5 | 10 | 16 | 15 | 7 | | | | | | 54 | 0 | 0 | 0 | 0 | 0 | -48 | 0 |
| 20-25 | | 3 | 5 | 19 | 18 | 9 | | | | | | | 54 | -1 | -54 | 54 | 83 | | -83 | 83 |
| 15-20 | | 3 | 11 | 12 | 3 | 3 | | | | | | | 32 | -2 | -64 | 128 | 144 | | -73 | 144 |
| 10-15 | 1 | | 3 | 1 | 3 | | | | | | | | 8 | -3 | -24 | 72 | 57 | | -19 | 57 |
| 5-10 | | 1 | | | | | | | | | | | 1 | -4 | -4 | 16 | 16 | | -4 | 16 |
| f | 1 | 8 | 24 | 46 | 48 | 50 | 53 | 30 | 15 | 19 | 4 | 2 | 300 | | 268 | 1670 | 1227 | -22 | 14 | 1205 |
| $x^1$ | -5 | -4 | -3 | -2 | -1 | -0 | -1 | -2 | -3 | 4 | 5 | 6 | | | | | | | | |
| $fx^1$ | -5 | -32 | -72 | -92 | -48 | 0 | 53 | 60 | 45 | 76 | 20 | 12 | 17 | | | | | | | |
| $fx^{1^2}$ | 25 | 128 | 216 | 184 | 48 | 0 | 53 | 120 | 135 | 304 | 100 | 72 | 1385 | | | | | | | |
| $y^1$ | -3 | -13 | -36 | -41 | -21 | 32 | 107 | 77 | 48 | 82 | 22 | 14 | 268 | | | | | | | |
| $x^1y^1$ | 15 | 52 | 108 | 82 | 21 | 0 | 107 | 154 | 144 | 328 | 110 | 84 | 1205 | | | | | | | |

$C_y = 0.89$ $C_x = 0.057$

$C_y^2 = 0.79$ $C_x^2 = 0.032$

$\sigma_y = 10.95$ $\sigma_x = 10.75$

$$r = \frac{\frac{1205}{300} - (0.057 \times 0.89)}{(2.19)(2.15)} = 0.84$$

Figure 1 :Scattergram and calculation of the product-moment coefficient of correlation between Forms A and B of the Edmonton Test of Equivalence in Mathematics for 300 Grade IX students

# APPENDIX C

Table 1. 300 Grade IX Scores on Forms A and B of the Edmonton Test of Equivalence in Mathematics with the Three Corresponding Criteria Scores for Determination of Test Validity.

Table 1 : 300 Grade IX Scores on Forms A and B of the Edmonton Test of Equivalence in Mathematics with the Three Corresponding Criteria Scores for Determination of Test Validity.

| | Edmonton Test of Equivalence | | Criteria Scores | | |
|---|---|---|---|---|---|
| Pupil No. | Form A | Form B | General T. | Math. Final | Grade IX Total Score |
| 1 | 60 | 61 | 120 | 96 | 428 |
| 2 | 60 | 60 | 133 | 96 | 496 |
| 3 | 58 | 56 | 120 | 92 | 447 |
| 4 | 56 | 53 | 133 | 100 | 494 |
| 5 | 56 | 51 | 121 | 89 | 430 |
| 6 | 55 | 57 | 141 | 95 | 460 |
| 7 | 53 | 61 | 140 | 99 | 486 |
| 8 | 53 | 56 | 138 | 84 | 463 |
| 9 | 54 | 50 | 132 | 81 | 391 |
| 10 | 53 | 49 | 116 | 80 | 426 |
| 11 | 53 | 49 | 123 | 71 | 417 |
| 12 | 53 | 44 | 121 | 74 | 422 |
| 13 | 54 | 54 | 117 | 75 | 369 |
| 14 | 52 | 48 | 121 | 79 | 402 |
| 15 | 52 | 48 | 133 | 72 | 386 |
| 16 | 52 | 47 | 124 | 83 | 465 |
| 17 | 51 | 48 | 121 | 82 | 429 |
| 18 | 50 | 47 | 127 | 66 | 310 |
| 19 | 51 | 47 | 117 | 88 | 421 |
| 20 | 51 | 47 | 128 | 82 | 411 |
| 21 | 51 | 40 | 129 | 78 | 488 |
| 22 | 51 | 40 | 111 | 75 | 374 |
| 23 | 50 | 51 | 118 | 93 | 424 |
| 24 | 50 | 50 | 129 | 91 | 485 |
| 25 | 49 | 48 | 105 | 72 | 319 |
| 26 | 48 | 46 | 127 | 59 | 382 |
| 27 | 50 | 46 | 124 | 100 | 425 |
| 28 | 48 | 43 | 117 | 87 | 276 |
| 29 | 49 | 42 | 108 | 65 | 285 |
| 30 | 48 | 47 | 137 | 93 | 499 |
| 31 | 47 | 44 | 119 | 80 | 443 |
| 32 | 47 | 44 | 118 | 76 | 369 |
| 33 | 47 | 43 | 115 | 57 | 372 |
| 34 | 47 | 40 | 108 | 50 | 266 |
| 35 | 47 | 34 | 122 | 76 | 432 |
| 36 | 46 | 51 | 119 | 74 | 338 |
| 37 | 46 | 38 | 126 | 69 | 349 |
| 38 | 45 | 48 | 124 | 70 | 413 |
| 39 | 45 | 46 | 105 | 73 | 353 |
| 40 | 45 | 36 | 104 | 71 | 351 |
| 41 | 44 | 43 | 113 | 62 | 339 |
| 42 | 44 | 43 | 111 | 73 | 358 |
| 43 | 44 | 42 | 99 | 52 | 287 |
| 44 | 44 | 40 | 110 | 56 | 361 |
| 45 | 44 | 38 | 129 | 78 | 447 |
| 46 | 44 | 36 | 116 | 58 | 304 |
| 47 | 44 | 36 | 117 | 64 | 328 |
| 48 | 44 | 34 | 95 | 57 | 254 |
| 49 | 43 | 44 | 122 | 55 | 301 |
| 50 | 43 | 43 | 122 | 74 | 387 |

TABLE 1 (continued)

| | | | | | |
|---|---|---|---|---|---|
| 51 | 43 | 42 | 115 | 52 | 258 |
| 52 | 43 | 41 | 114 | 74 | 285 |
| 53 | 43 | 40 | 106 | 62 | 404 |
| 54 | 43 | 40 | 114 | 71 | 394 |
| 55 | 43 | 39 | 124 | 82 | 435 |
| 56 | 42 | 41 | 109 | 59 | 333 |
| 57 | 42 | 35 | 124 | 89 | 459 |
| 58 | 42 | 30 | 118 | 60 | 382 |
| 59 | 41 | 43 | 112 | 73 | 377 |
| 60 | 41 | 42 | 113 | 59 | 333 |
| 61 | 41 | 43 | 114 | 50 | 360 |
| 62 | 41 | 41 | 110 | 52 | 312 |
| 63 | 41 | 41 | 113 | 71 | 420 |
| 64 | 42 | 37 | 111 | 81 | 326 |
| 65 | 41 | 31 | 114 | 76 | 398 |
| 66 | 40 | 42 | 101 | 59 | 343 |
| 67 | 40 | 41 | 106 | 69 | 321 |
| 68 | 41 | 40 | 126 | 69 | 418 |
| 69 | 40 | 40 | 116 | 59 | 351 |
| 70 | 40 | 36 | 109 | 57 | 341 |
| 71 | 39 | 47 | 114 | 70 | 382 |
| 72 | 39 | 46 | 117 | 72 | 364 |
| 73 | 39 | 46 | 115 | 84 | 413 |
| 74 | 39 | 43 | 119 | 74 | 317 |
| 75 | 39 | 43 | 127 | 56 | 372 |
| 76 | 39 | 42 | 122 | 57 | 335 |
| 77 | 39 | 43 | 108 | 66 | 316 |
| 78 | 39 | 42 | 105 | 63 | 332 |
| 79 | 39 | 40 | 127 | 78 | 389 |
| 80 | 39 | 39 | 123 | 70 | 434 |
| 81 | 39 | 34 | 112 | 54 | 302 |
| 82 | 39 | 33 | 123 | 46 | 355 |
| 83 | 38 | 43 | 127 | 65 | 386 |
| 84 | 38 | 41 | 115 | 84 | 365 |
| 85 | 38 | 40 | 115 | 60 | 279 |
| 86 | 38 | 38 | 114 | 57 | 334 |
| 87 | 38 | 36 | 119 | 57 | 382 |
| 88 | 38 | 35 | 105 | 57 | 340 |
| 89 | 38 | 33 | 112 | 73 | 338 |
| 90 | 38 | 32 | 117 | 71 | 353 |
| 91 | 38 | 32 | 103 | 60 | 343 |
| 92 | 37 | 44 | 107 | 59 | 385 |
| 93 | 37 | 42 | 105 | 57 | 329 |
| 94 | 37 | 41 | 106 | 54 | 371 |
| 95 | 37 | 40 | 120 | 71 | 377 |
| 96 | 37 | 39 | 120 | 65 | 321 |
| 97 | 37 | 36 | 116 | 62 | 308 |
| 98 | 37 | 33 | 123 | 54 | 352 |
| 99 | 37 | 32 | 118 | 53 | 301 |
| 100 | 37 | 28 | 119 | 47 | 346 |

TABLE 1 (continued)

| | | | | | |
|---|---|---|---|---|---|
| 101 | 37 | 26 | 102 | 47 | 264 |
| 102 | 36 | 42 | 119 | 66 | 369 |
| 103 | 36 | 41 | 102 | 82 | 340 |
| 104 | 36 | 41 | 106 | 36 | 290 |
| 105 | 36 | 40 | 105 | 57 | 307 |
| 106 | 36 | 39 | 104 | 56 | 302 |
| 107 | 36 | 40 | 107 | 66 | 310 |
| 108 | 36 | 38 | 106 | 66 | 290 |
| 109 | 36 | 38 | 109 | 60 | 342 |
| 110 | 36 | 34 | 109 | 50 | 305 |
| 111 | 36 | 34 | 107 | 70 | 328 |
| 112 | 36 | 27 | 111 | 49 | 268 |
| 113 | 36 | 26 | 102 | 47 | 288 |
| 114 | 35 | 43 | 122 | 52 | 360 |
| 115 | 35 | 41 | 111 | 58 | 323 |
| 116 | 35 | 39 | 105 | 62 | 321 |
| 117 | 35 | 38 | 122 | 61 | 341 |
| 118 | 35 | 38 | 120 | 54 | 366 |
| 119 | 35 | 32 | 109 | 69 | 337 |
| 120 | 35 | 32 | 96 | 50 | 253 |
| 121 | 35 | 29 | 118 | 90 | 463 |
| 122 | 35 | 29 | 109 | 55 | 305 |
| 123 | 35 | 29 | 109 | 46 | 327 |
| 124 | 34 | 44 | 123 | 59 | 315 |
| 125 | 34 | 41 | 119 | 57 | 352 |
| 126 | 34 | 39 | 112 | 49 | 273 |
| 127 | 34 | 38 | 104 | 57 | 327 |
| 128 | 34 | 38 | 107 | 45 | 303 |
| 129 | 34 | 36 | 127 | 63 | 398 |
| 130 | 34 | 36 | 123 | 59 | 403 |
| 131 | 34 | 34 | 116 | 47 | 330 |
| 132 | 34 | 34 | 110 | 61 | 359 |
| 133 | 34 | 30 | 95 | 49 | 220 |
| 134 | 34 | 29 | 125 | 52 | 351 |
| 135 | 34 | 24 | 123 | 54 | 404 |
| 136 | 34 | 23 | 120 | 59 | 366 |
| 137 | 33 | 42 | 143 | 63 | 370 |
| 138 | 33 | 40 | 113 | 58 | 321 |
| 139 | 33 | 41 | 111 | 48 | 337 |
| 140 | 33 | 36 | 118 | 36 | 288 |
| 141 | 33 | 33 | 117 | 72 | 378 |
| 142 | 33 | 30 | 117 | 71 | 375 |
| 143 | 33 | 28 | 113 | 59 | 380 |
| 144 | 33 | 27 | 100 | 37 | 247 |
| 145 | 33 | 24 | 100 | 54 | 345 |
| 146 | 33 | 22 | 99 | 56 | 220 |
| 147 | 32 | 28 | 98 | 59 | 220 |
| 148 | 32 | 27 | 96 | 64 | 285 |
| 149 | 32 | 26 | 106 | 52 | 253 |
| 150 | 33 | 26 | 110 | 53 | 312 |

TABLE 1 (continued)

| | | | | | |
|---|---|---|---|---|---|
| 151 | 32 | 22 | 102 | 54 | 316 |
| 152 | 32 | 22 | 98 | 47 | 245 |
| 153 | 32 | 21 | 120 | 51 | 299 |
| 154 | 31 | 45 | 117 | 56 | 307 |
| 155 | 31 | 40 | 117 | 83 | 400 |
| 156 | 31 | 17 | 121 | 50 | 337 |
| 157 | 31 | 34 | 106 | 54 | 295 |
| 158 | 31 | 29 | 119 | 50 | 323 |
| 159 | 31 | 28 | 109 | 57 | 308 |
| 160 | 31 | 27 | 116 | 73 | 405 |
| 161 | 30 | 25 | 111 | 58 | 362 |
| 162 | 30 | 36 | 111 | 52 | 311 |
| 163 | 30 | 36 | 110 | 70 | 307 |
| 164 | 30 | 31 | 98 | 65 | 284 |
| 165 | 30 | 30 | 115 | 61 | 373 |
| 166 | 30 | 28 | 104 | 48 | 259 |
| 167 | 30 | 27 | 119 | 34 | 279 |
| 168 | 30 | 26 | 115 | 55 | 306 |
| 169 | 30 | 24 | 98 | 59 | 309 |
| 170 | 30 | 22 | 120 | 51 | 305 |
| 171 | 30 | 18 | 131 | 52 | 384 |
| 172 | 29 | 34 | 102 | 55 | 295 |
| 173 | 29 | 28 | 102 | 50 | 261 |
| 174 | 29 | 25 | 97 | 30 | 174 |
| 175 | 29 | 24 | 120 | 48 | 357 |
| 176 | 29 | 23 | 107 | 54 | 273 |
| 177 | 30 | 19 | 92 | 36 | 245 |
| 178 | 28 | 37 | 102 | 54 | 239 |
| 179 | 28 | 33 | 96 | 50 | 186 |
| 180 | 28 | 31 | 119 | 50 | 320 |
| 181 | 30 | 29 | 105 | 24 | 279 |
| 182 | 28 | 28 | 96 | 81 | 270 |
| 183 | 28 | 27 | 108 | 42 | 271 |
| 184 | 28 | 27 | 110 | 52 | 381 |
| 185 | 28 | 25 | 108 | 54 | 326 |
| 186 | 28 | 24 | 107 | 45 | 256 |
| 187 | 28 | 24 | 109 | 38 | 274 |
| 188 | 28 | 21 | 113 | 52 | 333 |
| 189 | 28 | 21 | 120 | 44 | 286 |
| 190 | 28 | 13 | 107 | 42 | 311 |
| 191 | 28 | 11 | 86 | 36 | 256 |
| 192 | 27 | 40 | 110 | 60 | 401 |
| 193 | 27 | 31 | 108 | 74 | 313 |
| 194 | 27 | 29 | 109 | 53 | 276 |
| 195 | 27 | 29 | 121 | 51 | 357 |
| 196 | 27 | 28 | 118 | 43 | 308 |
| 197 | 27 | 26 | 122 | 56 | 348 |
| 198 | 27 | 24 | 83 | 51 | 225 |
| 199 | 27 | 24 | 106 | 51 | 287 |
| 200 | 27 | 23 | 110 | 48 | 298 |

TABLE 1 (continued)

| | | | | | |
|---|---|---|---|---|---|
| 201 | 27 | 22 | 126 | 38 | 338 |
| 202 | 26 | 35 | 83 | 44 | 198 |
| 203 | 26 | 31 | 120 | 60 | 394 |
| 204 | 26 | 27 | 109 | 47 | 313 |
| 205 | 26 | 27 | 93 | 44 | 252 |
| 206 | 26 | 23 | 105 | 44 | 292 |
| 207 | 26 | 22 | 104 | 47 | 295 |
| 208 | 26 | 20 | 97 | 49 | 228 |
| 209 | 25 | 29 | 107 | 44 | 266 |
| 210 | 25 | 29 | 100 | 45 | 230 |
| 211 | 25 | 27 | 101 | 66 | 278 |
| 212 | 25 | 25 | 111 | 37 | 303 |
| 213 | 25 | 24 | 103 | 51 | 343 |
| 214 | 25 | 24 | 111 | 50 | 284 |
| 215 | 26 | 22 | 103 | 48 | 243 |
| 216 | 25 | 21 | 100 | 52 | 261 |
| 217 | 25 | 20 | 112 | 35 | 241 |
| 218 | 25 | 16 | 111 | 49 | 268 |
| 219 | 25 | 15 | 114 | 36 | 194 |
| 220 | 25 | 15 | 109 | 37 | 262 |
| 221 | 25 | 14 | 112 | 37 | 237 |
| 222 | 24 | 28 | 112 | 34 | 228 |
| 223 | 24 | 26 | 88 | 63 | 324 |
| 224 | 24 | 25 | 104 | 45 | 286 |
| 225 | 24 | 24 | 117 | 38 | 239 |
| 226 | 24 | 21 | 111 | 36 | 305 |
| 227 | 24 | 18 | 86 | 31 | 230 |
| 228 | 23 | 35 | 102 | 61 | 282 |
| 229 | 23 | 34 | 116 | 46 | 303 |
| 230 | 23 | 31 | 110 | 72 | 383 |
| 231 | 23 | 27 | 99 | 40 | 236 |
| 232 | 24 | 25 | 103 | 19 | 198 |
| 233 | 24 | 25 | 103 | 59 | 276 |
| 234 | 23 | 24 | | | |
| 235 | 23 | 24 | 115 | 39 | 264 |
| 236 | 23 | 23 | 102 | 47 | 251 |
| 237 | 23 | 23 | 114 | 44 | 289 |
| 238 | 23 | 20 | 101 | 48 | 308 |
| 239 | 23 | 15 | 106 | 44 | 366 |
| 240 | 22 | 26 | 93 | 36 | 228 |
| 241 | 21 | 23 | 101 | 37 | 306 |
| 242 | 22 | 24 | 93 | 18 | 161 |
| 243 | 22 | 23 | 124 | 38 | 303 |
| 244 | 22 | 22 | 114 | 45 | 324 |
| 245 | 22 | 21 | 104 | 23 | 228 |
| 246 | 22 | 21 | 106 | 38 | 256 |
| 247 | 22 | 20 | 108 | 23 | 246 |
| 248 | 22 | 18 | 112 | 40 | 298 |
| 249 | 21 | 16 | 99 | 36 | 268 |
| 250 | 20 | 21 | 94 | 47 | 214 |

TABLE 1 (concluded)

| | | | | | |
|---|---|---|---|---|---|
| 251 | 21 | 22 | 106 | 53 | 300 |
| 252 | 21 | 21 | 104 | 9 | 272 |
| 253 | 21 | 19 | 105 | 42 | 231 |
| 254 | 21 | 18 | 101 | 31 | 203 |
| 255 | 21 | 17 | 112 | 47 | 295 |
| 256 | 21 | 17 | 109 | 34 | 285 |
| 257 | 21 | 16 | 98 | 43 | 321 |
| 258 | 20 | 30 | 103 | 44 | 257 |
| 259 | 20 | 29 | 87 | 42 | 184 |
| 260 | 20 | 28 | 114 | 47 | 373 |
| 261 | 20 | 27 | 86 | 37 | 197 |
| 262 | 20 | 24 | 110 | 39 | 272 |
| 263 | 20 | 20 | 115 | 30 | 251 |
| 264 | 20 | 19 | 107 | 38 | 246 |
| 265 | 20 | 17 | 94 | 30 | 216 |
| 266 | 20 | 16 | 101 | 21 | 226 |
| 267 | 20 | 14 | 97 | 44 | 251 |
| 268 | 19 | 22 | 101 | 53 | 287 |
| 269 | 19 | 20 | 98 | 38 | 234 |
| 270 | 19 | 19 | 110 | 39 | 257 |
| 271 | 19 | 18 | 107 | 43 | 257 |
| 272 | 18 | 17 | 112 | 37 | 238 |
| 273 | 19 | 12 | 89 | 44 | 282 |
| 274 | 18 | 29 | 102 | 49 | 264 |
| 275 | 18 | 25 | 99 | 43 | 256 |
| 276 | 18 | 24 | 96 | 36 | 200 |
| 277 | 18 | 15 | 110 | 38 | 286 |
| 278 | 17 | 29 | 100 | 34 | 206 |
| 279 | 17 | 25 | 99 | 40 | 325 |
| 280 | 17 | 18 | 107 | 28 | 224 |
| 281 | 17 | 17 | 105 | 34 | 239 |
| 282 | 17 | 16 | 108 | 32 | 314 |
| 283 | 16 | 28 | 104 | 38 | 249 |
| 284 | 16 | 24 | 108 | 40 | 281 |
| 285 | 16 | 15 | 106 | 40 | 315 |
| 286 | 16 | 11 | 100 | 28 | 227 |
| 287 | 15 | 20 | 83 | 45 | 224 |
| 288 | 15 | 19 | 110 | 49 | 243 |
| 289 | 15 | 18 | 98 | 31 | 285 |
| 290 | 15 | 17 | 90 | 44 | 220 |
| 291 | 15 | 13 | 106 | 27 | 236 |
| 292 | 14 | 27 | 86 | 32 | 157 |
| 293 | 14 | 23 | 101 | 43 | 247 |
| 294 | 14 | 16 | 90 | 34 | 237 |
| 295 | 13 | 24 | 81 | 57 | 225 |
| 296 | 13 | 23 | 107 | 42 | 243 |
| 297 | 12 | 15 | 84 | 18 | 162 |
| 298 | 13 | 9 | 85 | 23 | 212 |
| 299 | 11 | 16 | 79 | 17 | 135 |
| 300 | 9 | 14 | 81 | 29 | 139 |

APPENDIX C

Table 2. The Distributions of 300 Total Scores and Subtest Scores on Forms A and B of the Edmonton Test of Equivalence in Mathematics for Determination of Subtest Reliabilities and Intercorrelations.

Table 2 : The Distributions of 300 Total Scores and Subtest Scores on Forms A and B of the Edmonton Test of Equivalence in Mathematics for Determination of Subtest Reliabilities and Intercorrelations.

| Pupil No. | Total Score Form A | Total Score Form B | Computation Form A | Computation Form B | Denominate No. Form A | Denominate No. Form B | Algebra Form A | Algebra Form B | Geometry Form A | Geometry Form B |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 60 | 61 | 25 | 24 | 8 | 8 | 15 | 16 | 12 | 13 |
| 2 | 60 | 60 | 28 | 24 | 7 | 8 | 12 | 15 | 13 | 13 |
| 3 | 58 | 56 | 25 | 24 | 8 | 7 | 13 | 14 | 12 | 11 |
| 4 | 56 | 53 | 23 | 26 | 8 | 7 | 13 | 9 | 11 | 11 |
| 5 | 56 | 51 | 27 | 20 | 6 | 6 | 12 | 15 | 11 | 12 |
| 6 | 55 | 57 | 22 | 22 | 6 | 7 | 16 | 17 | 11 | 11 |
| 7 | 53 | 61 | 22 | 25 | 6 | 7 | 12 | 16 | 13 | 13 |
| 8 | 53 | 56 | 22 | 25 | 7 | 6 | 13 | 15 | 11 | 10 |
| 9 | 54 | 50 | 24 | 23 | 5 | 5 | 13 | 13 | 12 | 9 |
| 10 | 53 | 49 | 22 | 19 | 7 | 7 | 16 | 15 | 8 | 8 |
| 11 | 53 | 49 | 24 | 22 | 7 | 8 | 15 | 13 | 7 | 6 |
| 12 | 53 | 44 | 24 | 18 | 7 | 8 | 12 | 9 | 12 | 9 |
| 13 | 54 | 54 | 24 | 22 | 6 | 5 | 12 | 13 | 10 | 14 |
| 14 | 52 | 48 | 23 | 21 | 4 | 5 | 14 | 11 | 11 | 11 |
| 15 | 52 | 48 | 21 | 19 | 6 | 7 | 14 | 12 | 11 | 10 |
| 16 | 52 | 47 | 22 | 20 | 5 | 8 | 14 | 11 | 11 | 8 |
| 17 | 51 | 48 | 21 | 19 | 8 | 6 | 12 | 12 | 10 | 11 |
| 18 | 50 | 47 | 22 | 20 | 6 | 8 | 11 | 11 | 11 | 8 |
| 19 | 51 | 47 | 27 | 19 | 6 | 5 | 11 | 13 | 7 | 10 |
| 20 | 51 | 47 | 27 | 24 | 7 | 6 | 10 | 9 | 8 | 8 |
| 21 | 51 | 40 | 23 | 20 | 7 | 4 | 9 | 6 | 12 | 10 |
| 22 | 51 | 40 | 25 | 19 | 6 | 3 | 10 | 9 | 10 | 9 |
| 23 | 50 | 51 | 20 | 19 | 8 | 7 | 15 | 14 | 7 | 11 |
| 24 | 50 | 50 | 24 | 21 | 5 | 4 | 15 | 16 | 6 | 9 |
| 25 | 49 | 48 | 19 | 18 | 7 | 4 | 14 | 14 | 9 | 12 |
| 26 | 48 | 46 | 24 | 19 | 4 | 5 | 13 | 13 | 7 | 9 |
| 27 | 50 | 46 | 23 | 19 | 7 | 7 | 12 | 12 | 8 | 8 |
| 28 | 48 | 43 | 23 | 22 | 5 | 4 | 13 | 10 | 7 | 7 |
| 29 | 49 | 42 | 22 | 18 | 6 | 7 | 12 | 11 | 9 | 6 |
| 30 | 48 | 47 | 20 | 20 | 7 | 7 | 11 | 11 | 10 | 9 |
| 31 | 47 | 44 | 21 | 18 | 5 | 6 | 12 | 11 | 9 | 9 |
| 32 | 47 | 44 | 17 | 16 | 7 | 7 | 11 | 12 | 11 | 9 |
| 33 | 47 | 43 | 23 | 23 | 5 | 2 | 15 | 14 | 4 | 4 |
| 34 | 47 | 40 | 21 | 18 | 6 | 5 | 10 | 7 | 10 | 10 |
| 35 | 47 | 34 | 19 | 14 | 8 | 6 | 11 | 8 | 9 | 6 |
| 36 | 46 | 51 | 22 | 23 | 5 | 5 | 12 | 12 | 7 | 10 |
| 37 | 46 | 38 | 19 | 17 | 4 | 5 | 11 | 11 | 12 | 5 |
| 38 | 45 | 48 | 24 | 21 | 4 | 4 | 10 | 11 | 7 | 12 |
| 39 | 45 | 46 | 21 | 22 | 7 | 5 | 9 | 11 | 8 | 8 |
| 40 | 45 | 36 | 23 | 17 | 6 | 6 | 7 | 7 | 9 | 6 |
| 41 | 44 | 43 | 19 | 17 | 7 | 6 | 9 | 10 | 9 | 10 |
| 42 | 44 | 43 | 19 | 19 | 5 | 5 | 8 | 7 | 12 | 12 |
| 43 | 44 | 42 | 20 | 17 | 6 | 7 | 10 | 9 | 8 | 9 |
| 44 | 44 | 40 | 17 | 17 | 6 | 6 | 13 | 11 | 8 | 6 |
| 45 | 44 | 38 | 19 | 16 | 6 | 5 | 9 | 9 | 10 | 8 |
| 46 | 44 | 36 | 18 | 15 | 6 | 4 | 8 | 7 | 10 | 10 |
| 47 | 44 | 36 | 21 | 16 | 7 | 7 | 12 | 10 | 4 | 3 |
| 48 | 44 | 34 | 21 | 19 | 6 | 1 | 10 | 12 | 7 | 2 |
| 49 | 43 | 44 | 17 | 18 | 7 | 5 | 10 | 14 | 9 | 7 |
| 50 | 43 | 43 | 20 | 18 | 7 | 7 | 7 | 8 | 9 | 10 |

TABLE 2 (continued)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 51 | 43 | 42 | 21 | 19 | 5 | 3 | 12 | 12 | 5 | 8 |
| 52 | 43 | 41 | 21 | 18 | 5 | 8 | 13 | 11 | 4 | 4 |
| 53 | 43 | 40 | 18 | 19 | 6 | 5 | 14 | 12 | 5 | 4 |
| 54 | 43 | 40 | 19 | 18 | 6 | 6 | 8 | 10 | 10 | 6 |
| 55 | 43 | 39 | 21 | 16 | 6 | 8 | 7 | 8 | 9 | 7 |
| 56 | 42 | 41 | 17 | 16 | 5 | 6 | 9 | 8 | 11 | 11 |
| 57 | 42 | 35 | 22 | 17 | 3 | 3 | 7 | 7 | 10 | 8 |
| 58 | 42 | 30 | 19 | 12 | 4 | 5 | 11 | 7 | 7 | 6 |
| 59 | 41 | 43 | 20 | 18 | 6 | 7 | 9 | 9 | 6 | 9 |
| 60 | 41 | 42 | 17 | 14 | 5 | 5 | 13 | 13 | 6 | 10 |
| 61 | 41 | 43 | 16 | 20 | 5 | 5 | 11 | 9 | 9 | 9 |
| 62 | 41 | 41 | 20 | 22 | 6 | 4 | 12 | 12 | 3 | 3 |
| 63 | 41 | 41 | 20 | 19 | 5 | 5 | 9 | 9 | 7 | 8 |
| 64 | 42 | 37 | 22 | 19 | 5 | 4 | 10 | 8 | 5 | 6 |
| 65 | 41 | 31 | 19 | 15 | 8 | 7 | 6 | 7 | 8 | 2 |
| 66 | 40 | 42 | 15 | 20 | 7 | 8 | 8 | 7 | 10 | 7 |
| 67 | 40 | 41 | 17 | 19 | 5 | 5 | 10 | 8 | 8 | 9 |
| 68 | 41 | 40 | 19 | 19 | 5 | 6 | 12 | 8 | 5 | 7 |
| 69 | 40 | 40 | 20 | 19 | 7 | 5 | 8 | 8 | 5 | 8 |
| 70 | 40 | 36 | 16 | 14 | 6 | 3 | 13 | 12 | 5 | 7 |
| 71 | 39 | 47 | 15 | 17 | 7 | 3 | 11 | 12 | 6 | 12 |
| 72 | 39 | 46 | 18 | 20 | 4 | 4 | 10 | 15 | 7 | 8 |
| 73 | 39 | 46 | 16 | 17 | 5 | 7 | 11 | 12 | 7 | 10 |
| 74 | 39 | 43 | 19 | 18 | 5 | 5 | 9 | 10 | 6 | 10 |
| 75 | 39 | 43 | 16 | 20 | 5 | 6 | 9 | 7 | 9 | 10 |
| 76 | 39 | 42 | 19 | 22 | 3 | 2 | 7 | 10 | 10 | 8 |
| 77 | 39 | 43 | 16 | 20 | 6 | 3 | 9 | 12 | 8 | 8 |
| 78 | 39 | 42 | 17 | 17 | 7 | 7 | 6 | 9 | 9 | 9 |
| 79 | 39 | 40 | 20 | 17 | 6 | 6 | 5 | 7 | 8 | 10 |
| 80 | 39 | 39 | 22 | 17 | 4 | 5 | 8 | 11 | 5 | 6 |
| 81 | 39 | 34 | 15 | 15 | 6 | 6 | 9 | 6 | 8 | 7 |
| 82 | 39 | 33 | 16 | 15 | 6 | 3 | 11 | 10 | 6 | 4 |
| 83 | 38 | 43 | 19 | 16 | 6 | 6 | 5 | 10 | 9 | 12 |
| 84 | 38 | 41 | 16 | 16 | 5 | 5 | 9 | 10 | 8 | 10 |
| 85 | 38 | 40 | 16 | 19 | 6 | 7 | 10 | 8 | 6 | 6 |
| 86 | 38 | 38 | 17 | 15 | 6 | 5 | 7 | 9 | 8 | 9 |
| 87 | 38 | 36 | 19 | 18 | 4 | 5 | 10 | 8 | 5 | 5 |
| 88 | 38 | 35 | 18 | 13 | 6 | 5 | 7 | 9 | 7 | 8 |
| 89 | 38 | 33 | 19 | 15 | 6 | 6 | 11 | 10 | 2 | 2 |
| 90 | 38 | 32 | 19 | 15 | 6 | 5 | 9 | 9 | 4 | 3 |
| 91 | 38 | 32 | 16 | 15 | 4 | 4 | 10 | 8 | 8 | 5 |
| 92 | 37 | 44 | 16 | 18 | 5 | 7 | 8 | 9 | 8 | 10 |
| 93 | 37 | 42 | 16 | 21 | 6 | 3 | 9 | 11 | 6 | 7 |
| 94 | 37 | 41 | 15 | 16 | 3 | 5 | 10 | 11 | 9 | 9 |
| 95 | 37 | 40 | 13 | 15 | 7 | 7 | 8 | 8 | 9 | 10 |
| 96 | 37 | 39 | 16 | 16 | 6 | 6 | 7 | 8 | 8 | 9 |
| 97 | 37 | 36 | 17 | 15 | 6 | 3 | 8 | 12 | 6 | 6 |
| 98 | 37 | 33 | 19 | 17 | 5 | 4 | 7 | 7 | 6 | 5 |
| 99 | 37 | 32 | 19 | 15 | 6 | 5 | 9 | 10 | 3 | 2 |
| 100 | 37 | 28 | 15 | 15 | 5 | 4 | 11 | 6 | 6 | 3 |

TABLE 2 (continued)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 101 | 37 | 26 | 21 | 11 | 6 | 6 | 4 | 5 | 6 | 4 |
| 102 | 36 | 42 | 18 | 20 | 5 | 7 | 9 | 11 | 4 | 4 |
| 103 | 36 | 41 | 15 | 19 | 6 | 5 | 8 | 9 | 7 | 8 |
| 104 | 36 | 41 | 17 | 19 | 5 | 4 | 10 | 13 | 4 | 5 |
| 105 | 36 | 40 | 17 | 18 | 4 | 4 | 8 | 9 | 7 | 9 |
| 106 | 36 | 39 | 15 | 14 | 3 | 1 | 12 | 15 | 6 | 9 |
| 107 | 36 | 40 | 13 | 16 | 5 | 5 | 10 | 10 | 8 | 9 |
| 108 | 36 | 38 | 17 | 16 | 4 | 6 | 9 | 8 | 6 | 8 |
| 109 | 36 | 38 | 15 | 18 | 4 | 4 | 10 | 10 | 7 | 6 |
| 110 | 36 | 34 | 17 | 13 | 4 | 4 | 9 | 9 | 6 | 8 |
| 111 | 36 | 34 | 17 | 16 | 6 | 5 | 8 | 8 | 5 | 5 |
| 112 | 36 | 27 | 19 | 12 | 6 | 5 | 7 | 5 | 4 | 5 |
| 113 | 36 | 26 | 14 | 10 | 6 | 5 | 9 | 6 | 7 | 5 |
| 114 | 35 | 43 | 19 | 19 | 4 | 6 | 8 | 10 | 4 | 8 |
| 115 | 35 | 41 | 17 | 19 | 6 | 6 | 5 | 10 | 7 | 6 |
| 116 | 35 | 39 | 18 | 17 | 7 | 6 | 5 | 7 | 5 | 9 |
| 117 | 35 | 38 | 16 | 13 | 5 | 7 | 10 | 9 | 4 | 9 |
| 118 | 35 | 38 | 15 | 15 | 3 | 5 | 9 | 10 | 8 | 8 |
| 119 | 35 | 32 | 19 | 15 | 4 | 4 | 10 | 9 | 2 | 4 |
| 120 | 35 | 32 | 18 | 18 | 7 | 5 | 6 | 4 | 4 | 5 |
| 121 | 35 | 29 | 18 | 15 | 2 | 3 | 8 | 6 | 7 | 5 |
| 122 | 35 | 29 | 16 | 12 | 7 | 4 | 7 | 6 | 5 | 7 |
| 123 | 35 | 29 | 15 | 11 | 5 | 3 | 7 | 8 | 8 | 7 |
| 124 | 34 | 44 | 15 | 19 | 4 | 5 | 6 | 11 | 9 | 9 |
| 125 | 34 | 41 | 14 | 16 | 7 | 7 | 6 | 7 | 7 | 11 |
| 126 | 34 | 39 | 16 | 18 | 6 | 6 | 7 | 11 | 4 | 4 |
| 127 | 34 | 38 | 19 | 18 | 4 | 5 | 6 | 8 | 5 | 7 |
| 128 | 34 | 38 | 17 | 15 | 6 | 6 | 3 | 7 | 8 | 10 |
| 129 | 34 | 36 | 15 | 17 | 6 | 6 | 5 | 7 | 8 | 6 |
| 130 | 34 | 36 | 20 | 14 | 2 | 6 | 7 | 10 | 5 | 6 |
| 131 | 34 | 34 | 15 | 14 | 6 | 6 | 7 | 7 | 6 | 7 |
| 132 | 34 | 34 | 16 | 18 | 5 | 5 | 5 | 8 | 8 | 3 |
| 133 | 34 | 30 | 17 | 15 | 4 | 6 | 7 | 6 | 6 | 3 |
| 134 | 34 | 29 | 16 | 16 | 3 | 2 | 8 | 8 | 7 | 3 |
| 135 | 34 | 24 | 17 | 11 | 3 | 3 | 7 | 6 | 7 | 4 |
| 136 | 34 | 23 | 19 | 11 | 5 | 5 | 7 | 6 | 3 | 1 |
| 137 | 33 | 42 | 15 | 17 | 6 | 5 | 6 | 11 | 6 | 9 |
| 138 | 33 | 40 | 16 | 20 | 4 | 4 | 7 | 10 | 6 | 6 |
| 139 | 33 | 41 | 13 | 18 | 6 | 5 | 7 | 9 | 7 | 9 |
| 140 | 33 | 36 | 15 | 17 | 6 | 7 | 5 | 5 | 7 | 7 |
| 141 | 33 | 33 | 16 | 16 | 5 | 5 | 9 | 8 | 3 | 4 |
| 142 | 33 | 30 | 13 | 13 | 5 | 4 | 9 | 9 | 6 | 4 |
| 143 | 33 | 28 | 16 | 16 | 4 | 2 | 5 | 6 | 8 | 4 |
| 144 | 33 | 27 | 16 | 13 | 6 | 5 | 6 | 6 | 5 | 3 |
| 145 | 33 | 24 | 17 | 10 | 6 | 5 | 8 | 7 | 2 | 2 |
| 146 | 33 | 22 | 17 | 9 | 3 | 4 | 11 | 6 | 2 | 3 |
| 147 | 32 | 28 | 16 | 14 | 3 | 3 | 7 | 8 | 6 | 3 |
| 148 | 32 | 27 | 13 | 10 | 5 | 4 | 8 | 8 | 6 | 5 |
| 149 | 32 | 26 | 14 | 13 | 6 | 6 | 9 | 7 | 3 | 0 |
| 150 | 33 | 26 | 16 | 13 | 3 | 5 | 7 | 4 | 7 | 4 |

TABLE 2 (continued)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 151 | 32 | 22 | 15 | 11 | 5 | 4 | 6 | 2 | 6 | 5 |
| 152 | 32 | 22 | 13 | 9 | 6 | 4 | 8 | 7 | 5 | 2 |
| 153 | 32 | 21 | 17 | 11 | 3 | 4 | 11 | 5 | 1 | 1 |
| 154 | 31 | 45 | 18 | 20 | 5 | 7 | 5 | 11 | 3 | 7 |
| 155 | 31 | 40 | 14 | 16 | 5 | 5 | 8 | 12 | 4 | 7 |
| 156 | 31 | 17 | 17 | 8 | 6 | 6 | 8 | 3 | 0 | 0 |
| 157 | 31 | 34 | 15 | 17 | 4 | 5 | 5 | 7 | 7 | 7 |
| 158 | 31 | 29 | 15 | 12 | 3 | 3 | 9 | 10 | 4 | 4 |
| 159 | 31 | 28 | 17 | 18 | 3 | 3 | 9 | 6 | 2 | 1 |
| 160 | 31 | 27 | 20 | 16 | 3 | 3 | 6 | 6 | 2 | 2 |
| 161 | 30 | 25 | 17 | 13 | 1 | 2 | 7 | 8 | 5 | 2 |
| 162 | 30 | 36 | 15 | 16 | 3 | 3 | 10 | 12 | 3 | 5 |
| 163 | 30 | 36 | 12 | 16 | 3 | 4 | 6 | 8 | 9 | 8 |
| 164 | 30 | 31 | 14 | 15 | 2 | 1 | 9 | 12 | 5 | 3 |
| 165 | 30 | 30 | 18 | 15 | 3 | 7 | 5 | 6 | 4 | 2 |
| 166 | 30 | 28 | 14 | 11 | 4 | 3 | 5 | 7 | 7 | 7 |
| 167 | 30 | 27 | 13 | 10 | 6 | 6 | 5 | 3 | 6 | 8 |
| 168 | 30 | 26 | 15 | 13 | 3 | 4 | 6 | 5 | 6 | 4 |
| 169 | 30 | 24 | 12 | 10 | 4 | 1 | 11 | 10 | 3 | 3 |
| 170 | 30 | 22 | 15 | 13 | 4 | 5 | 8 | 2 | 3 | 2 |
| 171 | 30 | 18 | 15 | 9 | 5 | 3 | 8 | 6 | 2 | 0 |
| 172 | 29 | 34 | 10 | 12 | 6 | 5 | 10 | 11 | 3 | 6 |
| 173 | 29 | 28 | 13 | 14 | 5 | 4 | 5 | 4 | 6 | 6 |
| 174 | 29 | 25 | 19 | 13 | 2 | 2 | 8 | 9 | 0 | 1 |
| 175 | 29 | 24 | 18 | 13 | 3 | 5 | 6 | 4 | 2 | 2 |
| 176 | 29 | 23 | 12 | 10 | 6 | 6 | 6 | 4 | 5 | 3 |
| 177 | 30 | 19 | 17 | 11 | 3 | 3 | 7 | 3 | 3 | 2 |
| 178 | 28 | 37 | 16 | 14 | 4 | 5 | 6 | 9 | 2 | 10 |
| 179 | 28 | 33 | 13 | 15 | 4 | 5 | 7 | 7 | 4 | 6 |
| 180 | 28 | 31 | 12 | 14 | 4 | 4 | 7 | 8 | 5 | 5 |
| 181 | 30 | 29 | 16 | 14 | 3 | 3 | 4 | 5 | 7 | 7 |
| 182 | 28 | 28 | 14 | 15 | 4 | 4 | 8 | 9 | 2 | 1 |
| 183 | 28 | 27 | 13 | 14 | 4 | 5 | 5 | 4 | 6 | 4 |
| 184 | 28 | 27 | 15 | 11 | 2 | 3 | 6 | 6 | 5 | 7 |
| 185 | 28 | 25 | 12 | 11 | 2 | 2 | 10 | 8 | 3 | 4 |
| 186 | 28 | 24 | 16 | 14 | 2 | 4 | 8 | 4 | 2 | 2 |
| 187 | 28 | 24 | 14 | 11 | 6 | 5 | 7 | 6 | 1 | 2 |
| 188 | 28 | 21 | 15 | 12 | 3 | 2 | 6 | 5 | 4 | 2 |
| 189 | 28 | 21 | 14 | 11 | 3 | 4 | 6 | 5 | 5 | 1 |
| 190 | 28 | 13 | 14 | 7 | 7 | 3 | 5 | 3 | 2 | 0 |
| 191 | 28 | 11 | 13 | 7 | 3 | 3 | 6 | 0 | 6 | 1 |
| 192 | 27 | 40 | 13 | 17 | 5 | 5 | 6 | 10 | 3 | 8 |
| 193 | 27 | 31 | 14 | 18 | 2 | 3 | 8 | 8 | 3 | 2 |
| 194 | 27 | 29 | 12 | 14 | 4 | 4 | 6 | 9 | 5 | 3 |
| 195 | 27 | 29 | 13 | 12 | 1 | 3 | 9 | 11 | 4 | 3 |
| 196 | 27 | 28 | 17 | 14 | 3 | 5 | 5 | 9 | 2 | 0 |
| 197 | 27 | 26 | 15 | 16 | 3 | 4 | 7 | 6 | 2 | 0 |
| 198 | 27 | 24 | 15 | 11 | 3 | 3 | 8 | 7 | 1 | 3 |
| 199 | 27 | 24 | 12 | 12 | 3 | 3 | 4 | 6 | 8 | 3 |
| 200 | 27 | 23 | 14 | 10 | 2 | 3 | 5 | 7 | 6 | 3 |

TABLE 2 (continued)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 201 | 27 | 22 | 18 | 10 | 2 | 5 | 6 | 6 | 1 | 1 |
| 202 | 26 | 35 | 15 | 16 | 5 | 6 | 4 | 6 | 2 | 7 |
| 203 | 26 | 31 | 14 | 16 | 5 | 3 | 4 | 8 | 3 | 4 |
| 204 | 26 | 27 | 12 | 10 | 6 | 4 | 3 | 7 | 5 | 6 |
| 205 | 26 | 27 | 11 | 11 | 6 | 3 | 4 | 5 | 5 | 8 |
| 206 | 26 | 23 | 14 | 12 | 2 | 3 | 8 | 6 | 2 | 2 |
| 207 | 26 | 22 | 12 | 13 | 5 | 2 | 7 | 7 | 2 | 0 |
| 208 | 26 | 20 | 14 | 11 | 3 | 3 | 6 | 5 | 3 | 1 |
| 209 | 25 | 29 | 12 | 12 | 3 | 3 | 4 | 6 | 6 | 8 |
| 210 | 25 | 29 | 14 | 17 | 4 | 4 | 6 | 6 | 1 | 2 |
| 211 | 25 | 27 | 15 | 15 | 3 | 3 | 7 | 7 | 0 | 2 |
| 212 | 25 | 25 | 13 | 13 | 5 | 6 | 5 | 4 | 2 | 2 |
| 213 | 25 | 24 | 10 | 8 | 4 | 5 | 7 | 7 | 4 | 4 |
| 214 | 25 | 24 | 12 | 12 | 6 | 5 | 4 | 4 | 3 | 3 |
| 215 | 26 | 22 | 12 | 8 | 4 | 4 | 8 | 9 | 2 | 1 |
| 216 | 25 | 21 | 10 | 11 | 6 | 5 | 7 | 3 | 2 | 2 |
| 217 | 25 | 20 | 15 | 14 | 2 | 2 | 7 | 3 | 1 | 1 |
| 218 | 25 | 16 | 15 | 9 | 4 | 2 | 5 | 5 | 1 | 0 |
| 219 | 25 | 15 | 14 | 8 | 3 | 3 | 4 | 1 | 4 | 3 |
| 220 | 25 | 15 | 15 | 8 | 4 | 3 | 4 | 3 | 2 | 1 |
| 221 | 25 | 14 | 14 | 6 | 5 | 4 | 4 | 3 | 2 | 1 |
| 222 | 24 | 28 | 14 | 16 | 5 | 2 | 4 | 9 | 1 | 1 |
| 223 | 24 | 26 | 6 | 6 | 4 | 5 | 6 | 7 | 8 | 8 |
| 224 | 24 | 25 | 9 | 8 | 7 | 5 | 4 | 4 | 4 | 8 |
| 225 | 24 | 24 | 14 | 14 | 5 | 5 | 3 | 3 | 2 | 2 |
| 226 | 24 | 21 | 10 | 10 | 3 | 3 | 7 | 8 | 4 | 0 |
| 227 | 24 | 18 | 11 | 7 | 6 | 5 | 7 | 6 | 0 | 0 |
| 228 | 23 | 35 | 11 | 16 | 6 | 6 | 3 | 8 | 3 | 5 |
| 229 | 23 | 34 | 10 | 16 | 3 | 3 | 6 | 9 | 4 | 6 |
| 230 | 23 | 31 | 12 | 15 | 5 | 4 | 5 | 7 | 1 | 5 |
| 231 | 23 | 27 | 13 | 15 | 6 | 4 | 3 | 6 | 1 | 2 |
| 232 | 24 | 25 | 10 | 15 | 2 | 3 | 8 | 7 | 4 | 0 |
| 233 | 24 | 25 | 9 | 14 | 3 | 2 | 8 | 6 | 4 | 3 |
| 234 | 23 | 24 | | | | | | | | |
| 235 | 23 | 24 | 10 | 14 | 3 | 0 | 5 | 5 | 5 | 5 |
| 236 | 23 | 23 | 11 | 10 | 4 | 4 | 6 | 7 | 2 | 2 |
| 237 | 23 | 23 | 16 | 13 | 4 | 3 | 2 | 5 | 1 | 2 |
| 238 | 23 | 20 | 8 | 9 | 6 | 4 | 6 | 4 | 3 | 3 |
| 239 | 23 | 15 | 12 | 8 | 5 | 4 | 5 | 3 | 1 | 0 |
| 240 | 22 | 26 | 16 | 16 | 1 | 4 | 3 | 5 | 2 | 1 |
| 241 | 21 | 23 | 10 | 11 | 4 | 1 | 3 | 5 | 4 | 6 |
| 242 | 22 | 24 | 13 | 13 | 5 | 2 | 3 | 8 | 1 | 1 |
| 243 | 22 | 23 | 11 | 12 | 2 | 2 | 7 | 7 | 2 | 2 |
| 244 | 22 | 22 | 14 | 11 | 3 | 3 | 3 | 6 | 2 | 2 |
| 245 | 22 | 21 | 9 | 11 | 5 | 5 | 4 | 4 | 4 | 1 |
| 246 | 22 | 21 | 11 | 12 | 4 | 4 | 6 | 4 | 1 | 1 |
| 247 | 22 | 20 | 16 | 13 | 3 | 4 | 3 | 3 | 1 | 0 |
| 248 | 22 | 18 | 16 | 9 | 1 | 3 | 5 | 6 | 0 | 0 |
| 249 | 21 | 16 | 14 | 12 | 4 | 2 | 2 | 2 | 1 | 0 |
| 250 | 20 | 21 | 9 | 9 | 5 | 3 | 2 | 4 | 4 | 5 |

TABLE 2 (concluded)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 251 | 21 | 22 | 11 | 15 | 4 | 3 | 4 | 4 | 2 | 0 |
| 252 | 21 | 21 | 10 | 11 | 4 | 4 | 3 | 5 | 4 | 1 |
| 253 | 21 | 19 | 7 | 9 | 5 | 3 | 4 | 2 | 5 | 5 |
| 254 | 21 | 18 | 11 | 11 | 6 | 4 | 4 | 3 | 0 | 0 |
| 255 | 21 | 17 | 9 | 7 | 3 | 3 | 6 | 6 | 3 | 1 |
| 256 | 21 | 17 | 11 | 11 | 4 | 1 | 4 | 5 | 2 | 0 |
| 257 | 21 | 16 | 13 | 8 | 2 | 2 | 4 | 3 | 2 | 3 |
| 258 | 20 | 30 | 11 | 16 | 2 | 4 | 3 | 7 | 4 | 3 |
| 259 | 20 | 29 | 9 | 12 | 2 | 4 | 6 | 5 | 3 | 8 |
| 260 | 20 | 28 | 11 | 16 | 2 | 2 | 5 | 6 | 2 | 4 |
| 261 | 20 | 27 | 11 | 11 | 2 | 3 | 6 | 5 | 1 | 8 |
| 262 | 20 | 24 | 13 | 14 | 3 | 4 | 3 | 6 | 1 | 0 |
| 263 | 20 | 20 | 13 | 13 | 3 | 3 | 2 | 2 | 2 | 2 |
| 264 | 20 | 19 | 8 | 7 | 5 | 6 | 2 | 1 | 5 | 5 |
| 265 | 20 | 17 | 12 | 10 | 4 | 2 | 4 | 4 | 0 | 1 |
| 266 | 20 | 16 | 11 | 7 | 6 | 4 | 2 | 1 | 1 | 4 |
| 267 | 20 | 14 | 14 | 10 | 1 | 1 | 4 | 2 | 1 | 1 |
| 268 | 19 | 22 | 11 | 10 | 4 | 3 | 1 | 4 | 3 | 5 |
| 269 | 19 | 20 | 12 | 14 | 4 | 2 | 2 | 3 | 1 | 1 |
| 270 | 19 | 19 | 12 | 12 | 2 | 3 | 2 | 5 | 3 | 0 |
| 271 | 19 | 18 | 9 | 9 | 3 | 4 | 7 | 4 | 0 | 1 |
| 272 | 18 | 17 | 12 | 10 | 1 | 2 | 4 | 5 | 1 | 0 |
| 273 | 19 | 12 | 12 | 7 | 2 | 1 | 2 | 3 | 3 | 1 |
| 274 | 18 | 29 | 6 | 14 | 4 | 5 | 5 | 7 | 3 | 3 |
| 275 | 18 | 25 | 11 | 14 | 2 | 5 | 4 | 4 | 1 | 2 |
| 276 | 18 | 24 | 9 | 13 | 4 | 4 | 5 | 4 | 0 | 3 |
| 277 | 18 | 15 | 11 | 7 | 2 | 3 | 2 | 5 | 3 | 0 |
| 278 | 17 | 29 | 6 | 13 | 3 | 2 | 3 | 8 | 6 | 6 |
| 279 | 17 | 25 | 7 | 10 | 4 | 4 | 3 | 6 | 3 | 5 |
| 280 | 17 | 18 | 8 | 10 | 2 | 2 | 5 | 5 | 2 | 1 |
| 281 | 17 | 17 | 8 | 10 | 2 | 1 | 6 | 5 | 1 | 1 |
| 282 | 17 | 16 | 10 | 8 | 1 | 4 | 5 | 4 | 1 | 0 |
| 283 | 16 | 28 | 6 | 13 | 2 | 1 | 5 | 10 | 3 | 4 |
| 284 | 16 | 24 | 10 | 12 | 1 | 2 | 4 | 7 | 1 | 3 |
| 285 | 16 | 15 | 11 | 7 | 1 | 2 | 3 | 5 | 1 | 1 |
| 286 | 16 | 11 | 11 | 5 | 4 | 2 | 0 | 4 | 1 | 0 |
| 287 | 15 | 20 | 9 | 8 | 1 | 4 | 4 | 6 | 1 | 2 |
| 288 | 15 | 19 | 9 | 9 | 1 | 2 | 3 | 7 | 2 | 1 |
| 289 | 15 | 18 | 11 | 10 | 2 | 4 | 2 | 3 | 0 | 1 |
| 290 | 15 | 17 | 6 | 8 | 4 | 4 | 4 | 5 | 1 | 0 |
| 291 | 15 | 13 | 10 | 9 | 2 | 1 | 2 | 3 | 1 | 0 |
| 292 | 14 | 27 | 7 | 14 | 4 | 6 | 2 | 3 | 1 | 4 |
| 293 | 14 | 23 | 8 | 13 | 4 | 4 | 2 | 5 | 0 | 1 |
| 294 | 14 | 16 | 6 | 8 | 2 | 4 | 6 | 2 | 0 | 2 |
| 295 | 13 | 24 | 7 | 11 | 0 | 1 | 5 | 7 | 1 | 5 |
| 296 | 13 | 23 | 8 | 10 | 0 | 4 | 4 | 4 | 1 | 5 |
| 297 | 12 | 15 | 7 | 7 | 1 | 3 | 1 | 5 | 3 | 0 |
| 298 | 13 | 9 | 6 | 6 | 3 | 2 | 3 | 1 | 1 | 0 |
| 299 | 11 | 16 | 8 | 8 | 0 | 1 | 3 | 7 | 0 | 0 |
| 300 | 9 | 14 | 7 | 9 | 1 | 2 | 1 | 3 | 0 | 0 |